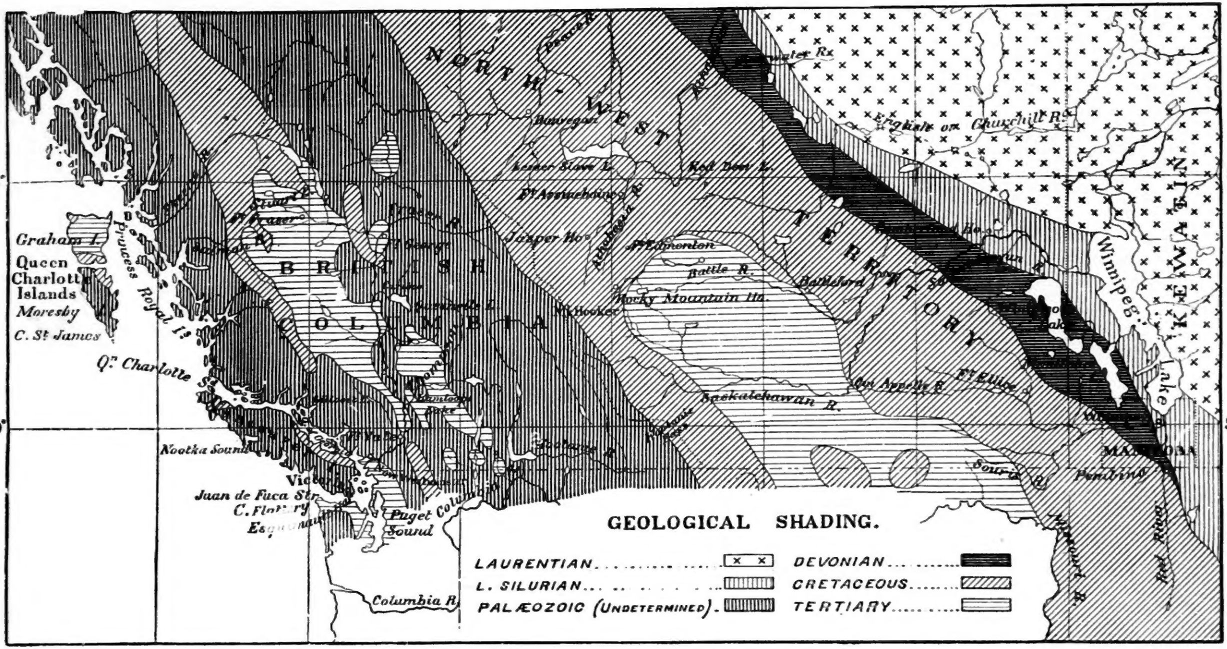

WESTERN CANADA.

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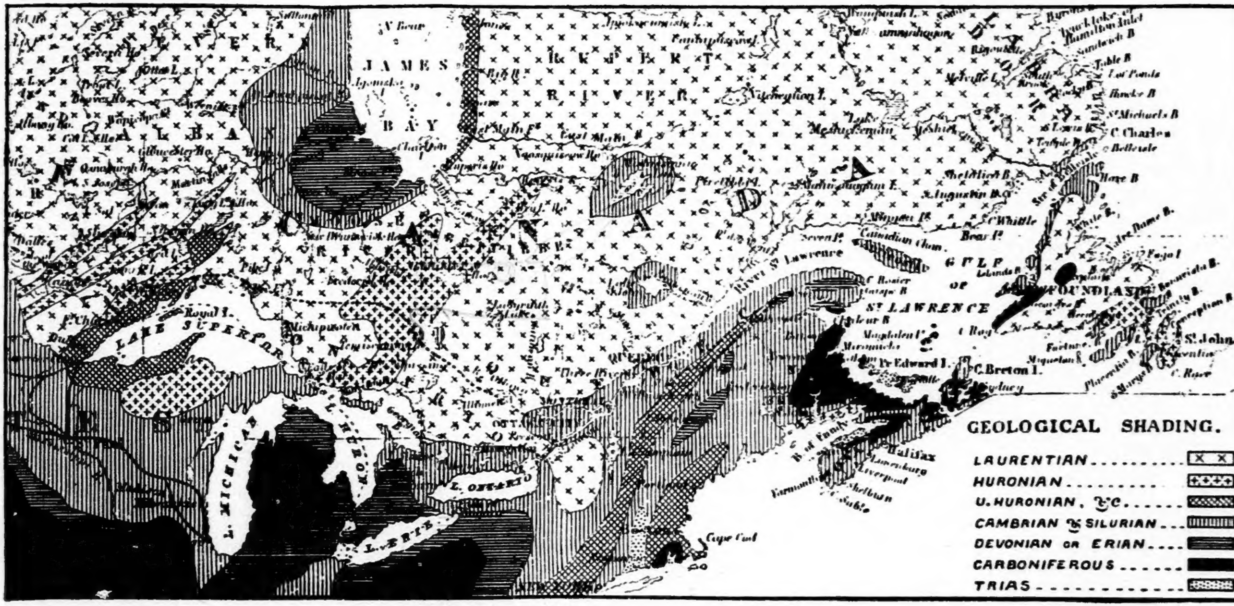

EASTERN CANADA.

LECTURE NOTES

ON

GEOLOGY

AND

OUTLINE OF THE GEOLOGY OF CANADA.

For the use of Students.

WITH

FIGURES OF CHARACTERISTIC FOSSILS.

BY

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LECTURE NOTES

ON

GEOLOGY,

FOR THE USE OF STUDENTS.

Geology, or, as it has been sometimes termed, *Geognosy*, is the scientific knowledge of the earth; or more particularly of that rocky crust of the earth on which its superficial features depend, which affords to us mineral products and soils, on which animals and plants exist, and in which are preserved the monumental records of the changes which our planet has experienced in past time.

Geology may be studied with reference to its practical pursuit as a method of scientific investigation, or with reference to the theories of the earth deducible from its facts, or with reference to its applications to the arts of life. These several aspects of the subject may be termed—

1. Practical Geology.
2. Theoretical Geology.
3. Applied Geology.

The first is that which should engage the attention of the student at the outset, as being preliminary to the successful cultivation of the others; but in studying it reference may be made to its bearings on the second and third.

Practical geology may be arranged under the following general heads:—

I. Lithology—or the study of *Rocks* as mineral aggregates and as materials composing the earth's crust. This study is best carried on with the aid of properly named hand specimens of minerals and rocks, and is much aided by chemical tests and by the examination of sections of rocks under the microscope.

II. Stratigraphy—or the consideration of the arrangement of the rocky masses of the earth on the large scale. This study requires the aid of maps and sections of the structure of portions of the earth, and is carried on in nature by the examination of natural sections and cliffs, quarries, mines, and other exposures of rocks.

III. Palæontology—or the study of the fossil remains of animals and plants imbedded in the earth's crust, in connection with the succession of deposits ascertained by stratigraphical investigation. This subject requires some preliminary knowledge of zoological and botanical classification, and is studied by comparison of museum specimens and by collecting and determining fossils.

IV. Historical Geology is the application of all the above to the geological history of the earth, and connects the elements of practical geology with the theory and application of the subject.

[In the regular University curriculum the student is supposed to have given some attention to the elements of Chemistry, Botany and Zoology. He is thus prepared in the ordinary course in Geology to enter on the study of Lithology, Stratigraphy and Palæontology, and in the honour course to go more fully into the determination of rocks and fossils, and into local stratigraphy and descriptive and theoretical geology.]

I. LITHOLOGY.

(1.) Chemistry of Rocks.

Of about sixty-three elements or simple substances known to chemistry, only sixteen enter into the composition of the more common rocks which constitute nearly the whole of the earth's crust. These are, in the order of their relative importance :—

Non-Metallic Elements.	*Metallic Elements.*
Oxygen.	Iron.
Silicon.	Aluminium.
Sulphur.	Calcium.
Chlorine.	Magnesium.
Carbon.	Sodium.
Hydrogen.	Potassium.
Fluorine.	Barium.
Phosphorus.	Manganese.

Of the above only Oxygen, Sulphur, Carbon and Iron can exist in nature in a pure or uncombined state. The more common minerals are all compounds of two or more elements.

Oxygen is the most important element in the crust of the earth, since in the ordinary rocks the other elements almost always occur in combination with this as oxides. Thus Silica or flint is Oxide ot Silicon, Alumina the earth of clay is Oxide of Aluminium, Lime is Oxide of Calcium. The ordinary ores of Iron are oxides of the metal.

Next to Oxygen the most important element is *Silicon*. Combining with Oxygen this forms Silica, and Silica has the property of combining with many other elements to form *Silicates*, which are the most common constituents of minerals and rocks. Of these Silicates the most abundant are those of Aluminium, Calcium, Magnesium and Potassium; and these are variously combined and mixed with one another to constitute the more complex minerals and rocks. Silicates sometimes contain water as an essential constituent, when they are termed *Hydrous Silicates*.

Other important Oxygen compounds are the *Carbonates*, *Sulphates* and *Phosphates*. Thus Calcium Carbonate is common Limestone, Calcium Sulphate is Gypsum, and Calcium Phosphate is Apatite or Bone-earth.

Some important constituents of rocks are not Oxides, as Sodium Chloride or common Salt, Calcium Fluoride or Fluorspar, Iron Bi-Sulphide or Iron Pyrite.

There is a peculiar group of minerals and rocks of organic origin into which Carbon enters as a principal ingredient. These are the Coals, Asphalt and Bitumen.

(2.) Mineralogy of Rocks.

Of the chemical compounds above referred to, those which constitute the majority of rocks are the following:—

1. Quartz or Silica.

2. Felspar.
3. Mica.
4. Hornblende.
5. Pyroxene.

} Anhydrous Silicates.

6. Talc. 7. Serpentine. 8. Chlorite.	Hydrous Silicates.
9. Calcite. 10. Dolomite. 11. Gypsum. 12. Apatite. 13. Fluor Spar. 14. Rock Salt.	Carbonates, Sulphate, Phosphate, Fluoride, and Chloride.
15. Magnetite. 16. Hematite. 17. Limonite. 18. Pyrite.	Oxides and Sulphide of Iron.
19. Coal. 20. Bitumen and Asphalt. 21. Graphite.	Carbonaceous Minerals.

1. QUARTZ.

As familiar examples, Flint and Rock Crystal may be taken. The former, occurring in concretions in chalk and other calcareous rocks, was probably one of the first mineral substances used by man; being the material of the flint implements of the "Stone age." As quartz is the most common of minerals, and occurs in most silicious rocks, it may serve as a typical mineral whereby to illustrate the terms used in other cases.

Composition.—Quartz when pure is *Silica*, a compound of the elements *Silicon* and *Oxygen*. The former is an element not unlike carbon or charcoal in many of its properties; the latter a gas and the most important ingredient of the atmosphere. Silica is thus an *Oxide of Silicon*, and containing two proportions of Oxygen to one of Silicon, its chemical name is *Silicon dioxide*.

Crystallization.—Its usual form is a six-sided prism, terminated by a six-sided pyramid. It thus belongs to the *Hexagonal* system of crystallization. When mineral substances solidify from the state of vapour, from solution in water, or from a state of fusion, their particles tend to arrange themselves along certain lines or axes, and thus to produce crystals of definite geometrical forms. The law in the case of Quartz is, that its particles arrange themselves along three horizontal axes, or lines of attraction, at angles of sixty degrees with each other, and along a fourth axis at right angles to the other three. The six-sided plates and six-rayed stars of snow are formed on the same principle.

Perfect crystals of Quartz are found lining *Geodes* or cavities in rocks, also the sides of fissures and veins, and sometimes imbedded in the substance of rocks. Small crystals confusedly aggregated, and imperfect, owing to pressure, give *Granular varieties.* Crystals so small that they cannot be discerned by the naked eye give *Crypto-crystalline varieties.*

Its Hardness is 7, measured by a scale in which Talc is 1 and Diamond 10. The hardness of Quartz is sufficient to enable it to scratch glass, to resist the action of steel, and to feel gritty in the teeth.

Its Specific Gravity is 2·5 to 2·8, measured by a scale in which water is the unit. It is thus two and a half times heavier than water. Quartz being one of the most common minerals, and entering very largely into the composition of rocks, in which also it is associated with many other substances not very different in specific gravity, it follows that its specific gravity is about that of most ordinary rocks; all of which are thus sufficiently heavy to sink readily in water, but when immersed in water lose between one half and one third of their weight.

Optical Characters.—Quartz is *colourless*, but becomes coloured by mixture with other substances, especially Oxides of Iron. The Protoxide (Ferrous Oxide) gives dull green and blackish colors—the Peroxide (Ferric Oxide) red colours, and the Hydrous Peroxide yellow and brown colours. The *Lustre* of Quartz is, with reference to its *kind*, *Vitreous* or that of broken glass. With reference to its *degree*, it varies from splendent, the lustre of perfect crystalline faces, to dull or lustreless. The vitreous lustre is a good character whereby to distinguish the mineral. The pure and crystalline varieties are *transparent;* the crypto-crystalline and coarse varieties *translucent* to *opaque.*

Quartz is *Brittle*, and its fracture *Conchoidal* in the pure varieties. It is *Infusible* and *Insoluble* in water and ordinary acids; but may be fused or dissolved in water, when combined with Alkalis, as Potash or Soda.

Varieties of Quartz.

Quartz presents many varieties, which may be arranged under the heads of (*a*) Crystalline or vitreous, and (*b*) Crypto-crystalline.

(*a*). *Vitreous Varieties.*

Rock Crystal.—Transparent and colourless, often in the definite crystalline form. Used for lenses, for ornamental purposes and to form imitation gems or doublets.

Amethyst.—Purple and violet varieties, coloured by a minute quantity of Manganese, or perhaps in some cases by Iron and Soda.

Rose Quartz.—A more delicately tinted pink variety.

Yellow and Smoky Quartz.—Called Cairngorm or false Topaz, of smoky or rich yellowish and brownish hues; coloured by Titanic Acid, or by organic matter.

Cat's Eye.—Transparent Quartz, containing fibres of asbestus, which give it a lustre resembling that of satin.

Aventurine is translucent quartz spangled with brilliant scales of yellow mica.

The glassy varieties of quartz pass into common *milky quartz.*

(*b*). *Crypto-crystalline Varieties.*

Chalcedony is the general name for colourless varieties having a glistening and somewhat waxy lustre.

Carnelian is a flesh-coloured or red chalcedony coloured by iron. A deeper red variety is called *Sard.*

Agate is chalcedony with bands or spots of different textures and colours. When these are in parallel layers it is called *Onyx.* Some of the layers being absorbent, colourless agates of this kind can be artificially coloured. When some of the layers are of carnelian or sard it is called *Sardonyx.* These banded varieties are the material of *Cameos.* When translucent Chalcedony is penetrated with moss-like or dendritic filaments of Oxide of Iron or Manganese it is *Moss agate* or *Mocha stone.*

Chrysoprase is a pale green variety coloured by Oxide of Nickel. Green varieties coloured merely by Iron are common *Prase.*

Flint and *Chert* are names for coarse Chalcedonic varieties, usually impure and of dull colours. A cellular variety is Buhr-stone, used for millstones.

Agates are produced by the deposition of Chalcedony in the cavities of rocks, usually those of volcanic or igneous origin. When this process is slow or intermittent, bands of various textures and colours are formed in succession. Flint and Chert are formed by the slow collection of silicious particles around centres, by concretionary action. Hence they often have fossil sponges, shells, &c., in their interior. Wood imbedded in rocks is often fossilized by silica, or silicified, so as to resemble Agate.

Jasper includes those varieties which are opaque and more or less deeply coloured, usually by Oxide of Iron. Red Jasper is one of the most common varieties; a brown clouded or banded Jasper is called *Egyptian Jasper;* green and red or green and yellow banded varieties, are *Riband Jasper;* a green variety with bright red spots is *Bloodstone* or *Heliotrope.*

Quartz occurs very largely in the earth's crust as sand, sandstone and quartz-rock or quartzite, and also as a constituent of many compound rocks.

2. FELSPAR.

There are several species of Felspar; but we may take as an example the most abundant and most important species, *Orthoclase or* common Felspar.

In *Chemical Composition* it is a Silicate of Alumina and Potash. It is not acted on by acids and is fusible with difficulty.

Its *Crystalline form* is monoclinic; its particles being arranged in accordance with three axes of crystallization—the two horizontal ones at right angles to each other, the third at an angle of 63°53′ to plane of the others. It has a perfect cleavage parallel with the base. These cleavage faces aid in distinguishing it from Quartz.

Its *Hardness* is 6, being thus next to Quartz in the scale of hardness. Though scratched by Quartz it is hard enough to scratch glass, but feebly.

Its *Specific Gravity* is 2·5 to 2·6.

Its *Lustre* is vitreous, but with a tendency to pearly on cleavage surfaces. It is white when pure, but often has red tints due to the presence of Ferric Oxide.

Kaolin, or the finest China Clay, proceeds from the decomposition of Felspar; the Potash being dissolved by rain water and leaving the Silica and Alumina in a fine state of division.

Of the other Felspars the most important are *Oligoclase* and *Albite*, Soda Felspars, in which Soda replaces the Potash of the Orthoclase, and *Labradorite* and *Anorthite*, Lime Felspars, in which a large proportion of Lime is present as well as Soda. Albite sometimes presents a beautiful pearly opalescence upon its cleavage faces, and Labradorite is remarkable for the splendid play of colours observed in some specimens. Labradorite, Anorthite and Oligoclase are basic, or have an excess of base relatively to their silica. All beside Orthoclase are triclinic.

The Felspars are extremely important in Geology as constituents of the Silicious Crystalline rocks, as Granite, Syenite, Gneiss, Dolerite, Porphyry, &c.

They enter very largely into the composition of the lavas of Volcanoes; those called *Trachytic Lavas* or *Trachytes*, consisting principally of Felspar.

3. MICA.

Of this also there are several Species: Common Mica or *Muscovite* is the most important.

It is a very complex Silicate, containing Silica, Alumina, Potash, Iron, Magnesia, Lime and Soda.

Its crystals are inclined rhombic and rectangular prisms (monoclinic.) The angles of the rhombic prisms are 120° and 60°. It is remarkable for its very perfect cleavage parallel to the base of the

prism. In this direction it may be split into extremely thin laminae which are flexible and elastic. When crystallized in small radiating plates it is called *Plumose Mica.*

H.—2·0 to 2·5. Gr.—2·75 to 3·1.

Its lustre on the faces of the cleavage planes is metallic pearly, and its colours range from silvery white to greenish, yellow and black. They are due to Oxides of Iron.

Along with Quartz it forms Mica-schist, and in a very fine state of division it is largely concerned in giving cleavage to roofing slate. It also gives a flaggy character to sandstone. In general when scales of Mica are arranged in parallel layers in rocks they give to these more or less of their own fissile character.

Biotite, a mica containing much magnesia and iron, and of a dark colour, is next in importance to Muscovite.

4. PYROXENE.

The name of this mineral, implying that it is a "Stranger to fire," is a reminiscence of the old controversies as to the origin of rocks from water or heat, and is curiously contrary to the fact that Pyroxene is one of the largest constituents of volcanic rocks.

Composition. Silica, lime, magnesia and iron. Some of the varieties have much more iron than others.

Crystalline form monoclinic or like that of Orthoclase, but the angles different, the inclination of the principal axis being 73° 59', and the acute angle of the rhombic prism, 87° 5', so that it is nearly square. It occurs also in granular and fibrous forms. Its cleavage is not perfect, but may be obtained parallel to the faces and bases of the prisms.

H.—5 to 6. Gr.— 3·2 to 3·5.

It is thus almost as hard as Felspar, and somewhat heavier than that mineral or quartz, so that rocks containing much Pyroxene are usually somewhat heavy.

It is colourless, but assumes the colours due to Ferrous Oxide, ranging from dull green to black. Its lustre is vitreous inclining to resinous, and in some varieties it becomes pearly.

Varieties.

These are very numerous and have received different names. We shall notice only a few of some geological importance.

Augite or common Pyroxene. This is of dark colour, usually black; and is the form in which the mineral most commonly occurs as an ingredient in rocks.

Sahlite and *Malacolite* are light green and white varieties, also occurring sometimes as considerable ingredients of rocks.

Diallage is a variety with a very distinct cleavage, and strong metallic pearly lustre on the surfaces.

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5. HORNBLENDE.

This is a mineral closely allied to Pyroxene. Its ordinary varieties, however, contain more magnesia and less lime than the latter.

Crystallisation monoclinic, but its rhombic prism is much flatter than that of pyroxene, its obtuse angle being 124° 30′, and it has a distinct cleavage parallel to the sides of the prism. It thus forms flat blade-like crystals, and these being often long and slender, it assumes fibrous forms.

H.—5 to 6. Gr.—2·9 to 3·4.

Its range of colour is similar to that of the last species.

Varieties.

Common Hornblende or Amphibole includes the dark and more massive varieties.

Actinolite is green, and columnar or fibrous.

Tremolite is white or gray, and finely fibrous.

Asbestus includes the finest fibrous varieties, which from the slenderness and flexibility of the fibres, may be woven into fabrics which have become celebrated as incombustible cloths.

Mountain Wood, Mountain Cork and *Mountain Leather* are fibrous and lamellar varieties resembling the substances whose names they bear.

6. TALC.

Is a silicate of Magnesia, with water. It is thus an example of a Hydrous Silicate.

Crystallization trimetric, and usually occurring in foliated or cleavable masses, the cleavage being similiar to that of Mica. It also occurs massive or crypto-crystalline.

H.—1. Gr.—2·5 to 2·8.

The low hardness of Talc affords a ready means of distinguishing it from other foliated minerals. It has also a soapy or unctuous feel, and its laminæ are not elastic.

Its colour is usually light green, though sometimes a silvery white. Its lustre is pearly.

Soapstone and Potstone, are compact or confusedly crystalline varieties, used for firestones for furnaces, or vessels required to stand the fire.

French Chalk is a variety used for marking.

Meerschaum is closely allied to Talc, but has a larger proportion of water.

Talc is an ingredient in Talc Schists, to which it communicates its own foliated character.

7. CHLORITE.

This represents a group of several species or sub-species. Chlorite may be regarded as a Hydrous Silicate of Alumina, Magnesia, and Iron. It occurs in foliated masses and flat crystals, of a greenish colour and slightly pearly lustre. It is harder than Talc, and its laminæ are not elastic. It is the leading ingredient of Chlorite Schists.

8. SERPENTINE.

This is a Silicate of Magnesia with water, the latter in larger quantity than in Talc. It usually occurs massive, and sometimes fibrous. It sometimes constitutes considerable rock masses.

H.—2·5 to 4. Gr.—2·5 to 2·6.

Its colour is usually green, and its lustre somewhat resinous or waxy.

Precious Serpentine, includes varieties of a rich green colour and translucent. *Common Serpentine*, includes the more dull-coloured and opaque varieties. *Picrolite and Chrysolite* are fibrous varieties. *Ophiolite* or *Verde Antique Marble*, consists of a mixture of Serpentine and Calcite, and is usually of green and white colours.

9. CALCITE.

Is Calcium carbonate, or common Limestone. Its effervescence with acids, owing to the disengagement of gaseous Carbonic Acid, is one of the ready ways of distinguishing it. Its inferior hardness, enabling it to be easily scratched with a knife, aids in distinguishing it from Quartz, Felspar and other hard silicious minerals.

Crystallization hexagonal. It occurs in many forms belonging to this system; especially the six-sided prism, the rhombohedron and the scalenohedron. It has very distinct cleavage parallel to the faces of the rhombohedron. It occurs also in granular, fibrous and crypto-crystalline states, as well as in earthy conditions.

H.—3. Sp. Gr.—2·5 to 2·8.

It is colourless, but is often coloured by other substances, especially Oxides of Iron and Carbonaceous matter. Its lustre is vitreous, inclining to pearly on the cleavage faces. It varies from transparent to opaque. The transparent varieties known as *Iceland Spar* possess double refraction.

Varieties.

Calcareous Spar, includes the perfectly crystalline forms.

Satin Spar, is a fibrous form occurring in veins, and having a silky lustre.

Calc Sinter, is a general name, which may include the imperfectly crystalline conditions occurring in *Stalactites* and *Stalagmite*, *Congealed water*, *Gibraltar Spar*, and *Calcareous Tufa*. All these varieties are deposited from solution in water, aided by an excess of carbonic acid.

10. DOLOMITE.

This is Calcium and Magnesium carbonate. It effervesces less readily with acids than Calcite. Its crystallization is rhombohedric like that of Calcite, except that the angles of its rhombohedron are slightly different, and it is a little harder and heavier. It has also a more pearly lustre.

Dolomite occurs in nature in the same manner as Calcite, but often contains ferrous carbonate, which causes it to assume a rusty colour in weathering.

11. GYPSUM.

Sulphate of Calcium with a large proportion of water (about 20 per cent). Its crystallization is monoclinic, and it has a very distinct cleavage, parallel to the larger faces of the rectangular prism. It is found in foliated, fibrous and granular crystallizations, and sometimes occurs in thick beds. Finely granular and translucent varieties are used for ornamental purposes, under the name of soft or gypseous alabaster. Its softness, enabling it to be scratched with the finger nail, and its pearly lustre, are distinguishing characters.

H.—1·5 to 2. Gr.—2·31 to 2·33.

Its lustre is pearly upon the cleavage faces. It is colourless, but frequently stained red by Peroxide of Iron, and sometimes black by carbonaceous matter.

Selenite is a lamellar variety of gypsum. Fibrous varieties are used to imitate Cat's eye.

The readiness with which Gypsum parts with its water when heated, and resumes it, becoming solid or setting, when mixed with water, gives the substance important economical uses for casting, plastering and cements. It is the cheapest means of supplying Sulphuric Acid to the soil, and to manures, and thus is of some value in agriculture.

Anhydrite is gypsum without water. It is found with the previous species, from which it differs in its greater hardness and specific gravity, and its trimetric crystallization. It is sometimes used as an ornamental stone in the same manner as marble.

12. APATITE.

This is Calcium Phosphate, and is of great interest as representing the earthy part of the bones of animals.

Its crystallization is hexagonal, and its usual form, is the hexagonal prism.

H.—5. Gr.—3· to 3·2.

Its lustre is resinous, and its colour usually greenish.

In the crystalline state it occurs largely in veins and beds in the Laurentian formation in Canada. It is also found in concretionary masses, in beds of various geological ages, and is the principal constituent of the harder varieties of Guano.

Calcium Phosphate is an essential ingredient in soils, in which it is usually present in very small quantity, and it is rapidly removed by those crops which produce the greatest amount of animal food. This gives to it a very great importance in agriculture, and it is much sought for in every civilized country, and largely used as a means of improving the soil.

13. FLUOR SPAR OR FLUORITE.

This is Calcium Fluoride. Its crystalline form is monometric, and it often occurs in beautiful and regular cubes, with a cleavage parallel to the faces of the octahedron.

H.—4. Gr.—3·1 to 3·2.

It is colourless, but is of blue and purple colours, and sometimes red or yellow.

It frequently occurs in metallic veins, more especially with the ores of load. It has been used as a flux in reducing metallic ores, hence its name Fluor.

14. ROCK SALT.

Common Salt is Sodium Chloride. It crystallizes in the monometric system, usually in cubes.

H.—2. Gr.—2· to 2·7.

It furnishes an excellent example of a soluble native Salt. It occurs not only in great quantity in the sea and in salt lakes, but also in extensive beds in the crust of the earth, whence it is mined for use. These beds have probably been formed by the drying up of salt lakes, and of isolated portions of sea water, and the subsequent covering by sediment of the beds of salt thus formed. Copious salt springs often rise from such deposits.

15. MAGNETITE.

Is an Oxide of Iron intermediate between the Monoxide and Sesquioxide. Crystallization monometric, usually in octahedrons.

H.—5·5 to 6·5. Gr.—5.

Colour black, Lustre metallic. It occurs in Canada in large beds, in the Laurentian, and also in layers as Iron Sand, and is the most valuable of the ores of Iron. It is attracted by the magnet, and it sometimes has itself magnetic polarity, constituting the natural loadstone. It is distinguished from the other species by its black powder or streak and its magnetic properties.

16. HEMATITE.

Also called Specular Iron, is Sesquioxide of the metal. Its crystallization is Hexagonal, and it often occurs in thin plates or scales, and also in fibrous forms.

H.—5·5 to 6·5. Gr.—4·5 to 5·3.

Its colour is black or steel grey, but its streak or powder is deep red. It is not usually attracted by the Magnet.

Foliated varieties constitute *Micaceous Iron Ore*, compact or fibrous dull red varieties are called *Hematite*, and earthy varieties are *Red Ochre*. It is a very valuable ore of Iron.

17. LIMONITE.

This is Hydrous Sesquioxide of Iron. It occurs in fibrous and concretionary masses.

H.—5· to 5·5. Gr.—3·6 to 4.

Its colour is dark brown, and its streak or powder yellow. Compact and fibrous varieties are called *Brown Hematite*. Concretionary varieties found in modern deposits are *Bog Iron Ore*, and earthy varieties are *Yellow Ochre*. It is a valuable ore of Iron.

18. PYRITE.

Is Disulphide of Iron. Crystallization monometric, usually in cubes and octahedrons.

H.—6· to 6·5. Gr.—4·8 to 5.

Colour, bronze yellow. It is a very common mineral, and is often mistaken for gold and for valuable metallic ores. When mixed with metallic ores and with coal it is a troublesome impurity; but it is used as source of Sulphur and Sulphuric Acid, and of the Ferrous Sulphate.

19. COAL.

Coal essentially consists of compounds of Carbon and Hydrogen, with variable amounts of Oxygen, of Nitrogen and of earthy matter. It presents many varieties, which shade into each other and differ much in composition and physical properties. This results from the fact that it is not a definite chemical compound, or crystallized mineral species, but rather a product of the partial decomposition of vegetable matter buried in the earth.

Its vegetable origin is proved by the remains of plants imbedded in it, and often showing their structure distinctly under the microscope, and by its resting on under-clays containing roots of trees, overlaid with shales filled with impressions of plants. It is of different geological ages, but the greater part was formed at a particular part of the earth's geological history, known as the Carboniferous period.

Its hardness varies from 1· to 2·5, and its sp. grav. from 1· to 1·8. Its colour is black, or dark brown, its powder either black or brown. Its lustre is resinous or sub-metallic, and its fracture conchoidal or flat. It usully presents a laminated structure, with layers of mineral charcoal, or of vegetable debris, or of earthy matter, between the laminæ, which often consist principally of flattened trunks of which the coal has been made up.

The principal varieties are the following :—

Brown Coal, is an imperfect coal found in the more modern formations. It is often merely a consolidated peat, but when composed of flattened trunks of trees, it assumes the compact form of jet It is intermediate in composition between Coal and Wood. It contains from 47 to 70 per cent of carbon. and from 5 to 18 per cent of Hydrogen, the remainder being Oxygen and ashes. It is usually an inferior kind of fuel.

Bituminous Coal, or ordinary black coal, proceeds from a more perfect carbonization of vegetable matter, and is the coal of the true Carboniferous system. The coking varieties become soft when heated, and burn with much flame. The non-coking varieties do not soften, and contain less gaseous matter. Bituminous coal contains from 75 to 90 per cent of Carbon, and from 3 to 6 per cent of Hydrogen, the remainder being principally Oxygen and ashes. The Bituminous varieties are used for the production of gas.

Anthracite, proceeds from the alteration of Bituminous coals, and is sometimes of the nature of natural coke. It is harder and heavier than the Bituminous coals, and contains from 85 to 92 per cent of Carbon, and from 2 to 3 per cent of Hydrogen. It gives little or no flame in burning. In some coal deposits, Anthracite passes by a further process of alteration into Graphite or Plumbago, which is however regarded as a distinct mineral species, owing to its very different physical properties.

20. BITUMEN.

Mineral oil and mineral pitch are mixtures of different hydro-carbons differing from coal in their liquid, viscid or easily fusible character, and in being soluble in oil of turpentine and ether. Like coal, these substances are derived from the chemical change of vegetable matter buried in the crust of the earth ; but they result chiefly from marine vegetation, or from that which has been buried and excluded from the air while still recent.

Petroleum, or mineral oil, includes the liquid or viscid varieties which flow from natural oil wells, or are obtained by boring into the beds of rock containing this substance in their pores or fissures. It has been known and used from the most ancient times, but has recently acquired greater importance from the abundance of it obtained by boring, and the means discovered for its purification. Petroleum often contains more than 12 per cent of Hydrogen.

Asphaltum, includes the solid and semi-solid varieties, having a specific gravity similar to that of coal, and pitchy lustre with a black or brownish black colour. It contains from 7 to 9 per cent of Hydrogen, and sometimes a considerable proportion of Oxygen and some earthy impurities. It is found in veins and beds, and has proceeded from the alteration and hardening of petroleum, owing to the loss of its more volatile ingredients.

Albertite, and "*Levis Coal*," are asphaltic minerals still further altered, until they assume nearly the appearance and composition of the bituminous coals. They are found in veins or fissures, and not in beds like the true coals, and have no vegetable structure. In some altered rocks materials of this kind have been converted into Anthracite and probably into Graphite.

Earthy Bitumen, and *Cannel Coal* are materials of this series, mixed with much earthy matter, and hardened until they resemble true coals. They are found in beds associated with the ordinary coals, and are much used in gas-making and for the distillation of Coal Oil.

It will be seen that the Coals and Bitumens form two parallel series, according to the amount of chemical change which they have experienced, thus:—

COAL SERIES.	BITUMEN SERIES.
Vegetable Matter.	Vegetable Matter.
Peat.	Petroleum.
Brown Coal.	Asphaltum.
Bituminous Coal.	Cannel Coal.
Anthracite Coal.	Anthracite.
Graphite.	Graphite.

21. GRAPHITE.

This substance is Carbon with its molecules arranged in a peculiar manner, constituting an allotropic form. Its crystalline form is hexagonal, in flat six-sides tables.

H.—1. to 2. Gr.—2.

Colour black and steel grey; Streak black. Lustre metallic. Divides into thin laminæ, flexible and greasy to touch.

Graphite is probably in most cases a coal or asphalt, altered by heat, and in this way it is often formed accidentally in furnaces. It is largely used in making crucibles for melting metals, in coating iron castings, in lessening the friction of machinery, and in drawing and writing. Its common names of "Black Lead" and Plumbago are inappropriate, as it contains no lead. The name Graphite is derived from its use in writing.

[For the numerous other species of minerals occurring disseminated in rocks or in veins and other repositories, the student is referred to text books of Mineralogy.]

(3.) Lithology Proper.

Some rocks, as quartz rock and limestone, are definite chemical compounds, and consist of one mineral species only; but even these are often mixed with foreign matters; and the greater part of rocks are mixtures of different mineral substances in various proportions. As these mixtures are regulated by no definite law of proportion, it follows that such rocks pass into each other by indefinite gradations. Hence the nomenclature and classification of rocks are attended with many difficulties.

For purposes of practical geology it is important to consider the classification of rocks under three aspects.

1. With reference to their *Origin*, rocks may be :—

(a) *Aqueous* or *Sedimentary*, that is, they may have been deposited as sediments, as sand, clay, &c. in water, and such deposition may have been aided or modified by accumulations of organic matter, as shells, corals, drifted plants, &c.

(b) *Igneous* or *Aqueo-igneous*—products of the action of heat in the interior of the earth. Of this kind are lavas, scoriæ, pumice, and volcanic ashes.

(c) *Metamorphic*—that is they may be sediments or volcanic beds which have been so modified by heat or pressure as to assume a crystalline condition accompanied in many cases by some chemical change.

2. With reference to their *Predominant Chemical Ingredients*, rocks may be regarded as (a) *Silicious*, (b) *Argillaceous*, (c) *Calcareous*, (d) *Carbonaceous*, (e) *Ferruginous*. The Silicious rocks, which are by far the most abundant, may further be divided into those that are *Acidic* or have an excess of Silica, and those that are *Basic* or have an excess of the elements with which the Silica is combined.

3. With reference to their *Texture*, rocks may be :—

(a) *Fragmental*, or composed of broken-up remains of older rocks. Of this kind are conglomerates, sandstone and clay.

(b) *Crystalline*, or composed of crystals of one or more minerals united together. Of this kind are granite and crystalline marble.

(c) *Organic*, or retaining the structure of organic bodies, as coral and crinoidal limestones, and coals.

The above grounds of classification are of course allied with each other. Thus fragmental rocks are for the most part aqueous. The crystalline rocks are for the most part of igneous or metamorphic origin, though some, like gypsum and rock salt, are aqueous. We may thus adopt one of the above arrangements as the dominant or general one, and use the others in subordination to it; and the first consideration or that of *origin* is probably at present the most available for the larger groups. Our general division of rocks may therefore be as follows :—

Class I. Igneous Rocks, including (1) *Volcanic* or *Superficial.* (2) *Hypogene* or *Nether.*

Class II. Aqueous Rocks, including (1) *Unaltered.* (2) *Altered* or *Metamorphic.*

Class I.—IGNEOUS ROCKS.

Section 1. Volcanic.

These are superficial products of Igneous action. All of them are Silicates, having usually Aluminium, Calcium and Magnesium as the principal bases. They may be divided into sub-sections, in accordance with the proportions of acid and base, as follows :—

Sub-section 1. *Basic Volcanic Rocks.*

Doleritic Lava is poured forth in a molten state by modern volcanoes, and consists of Pyroxene with basic Felspars. It generally presents a vesicular appearance, caused by the expansion of included vapours and gases, and it has usually a dark colour caused by the presence of iron in low states of oxidation. In ancient lavas the vesicles often become filled by aqueous infiltration with various minerals, when the texture of the rock is said to be Amygdaloidal.

Basalt is a dark-coloured finely crystalline compact lava which often exhibits columnar structure.

Sub-section 2. *Acidic Volcanic Rocks.*

Trachytic Lava is a light-coloured lava containing an excess of Silica, and produced by volcanoes in the same manner with ordinary lava. It is vesicular, and when highly so passes into *Pumice.*

Trachyte is a more compact rock of the same character, consisting chiefly of orthoclase, usually with a little hornblende and mica. When quartz is present it becomes *Quartz-trachyte.* It is more or less finely crystalline, and sometimes has imbedded crystals of orthoclase felspar, giving it the texture known as *porphyritic.*

Obsidian and *Pitchstone* are volcanic glasses of similar composition to trachyte but vitreous in texture.

To this section belong volcanic *Agglomerate* and volcanic *Tuff*. These are fragmental deposits made up of the stones and dust ejected from volcanic orifices. Their materials may either be those of the basic or acidic lavas or a mixture of both. They are strictly volcanic rocks, though their materials are often arranged in beds and subsequently consolidated by the action of water.

Section 2. Plutonic.

These are the nether or underlying products of igneous action. Being slowly cooled they are more highly crystalline than the rocks of the previous section, and having been consolidated at great depths below the surface, they do not become visible till after the removal of the more superficial volcanic products. Hence the rocks of this section visible at the surface are usually of greater age than the volcanic rocks.

Sub-section 1. *Basic Plutonic Rocks.*

Dolerite consists of the same material with Doleritic lava, and passes into it; but its more crystalline varieties may be regarded as Plutonic. When it contains hydrous minerals, as chlorite, it constitutes the variety *Diabase*.

Diorite or Greenstone is a crystalline mixture of Hornblende, usually dark coloured or greenish, with a triclinic felspar. This and the previous rock present great varieties of coarse and fine crystallization.

Syenite is a crystalline mixture of Hornblende and Orthoclase or Potash Felspar. By the addition of quartz it becomes an acidic rock and passes into Hornblendic Granite.

Sub-section 2. *Acidic Plutonic Rocks.*

Granite is a crystalline mixture of Felspar (Orthoclase with Oligoclase, or Albite) with Quartz and Mica. It may be coarse or fine grained, and sometimes becomes porphyritic by the admixture of large felspar crystals. *Hornblendic* or *Syenitic Granite* contains hornblende with or instead of mica. *Protogine* contains talc as well as mica. *Graphic Granite* is a variety found in veins. It is destitute of mica, and has the quartz arranged in plates in accordance with the cleavage of the felspar.

Felsite is a hard, finely crystalline or compact mixture of Felspar and Quartz. It is sometimes called *Petrosilex* and *Felstone*. When distinct crystals of orthoclase felspar are developed in it the porphyritic texture is produced. This is ordinary or *Felsite porphyry*, but other igneous rocks may assume the porphyritic structure.

The above are only a few of the more ordinary igneous rocks which should be known to the student by specimens and if possible also by their microscopic structure.

Class II.—AQUEOUS ROCKS.

Section 1. Unaltered Aqueous Rocks.

These may be produced either by the mechanical distribution of sediment in water, by chemical precipitation, or by the accumulation of the remains of animals and plants. The principal kinds are the following :—

Conglomerate consists of pebbles of hard, usually silicious, rocks, united by a paste or cement which may be silicious, argillaceous, calcareous or ferruginous. Conglomerates are beds of gravel, and they indicate the somewhat powerful action of water as an abrading and removing agent. They have often been formed along old lines of coast, and are consequently irregular in their bedding and limited in their horizontal distribution. The terms *Volcanic Breccia* and *Agglomerate* are applied to rocks composed of angular fragments. Volcanic agglomerate has already been referred to; but besides this Breccias are accumulated by aqueous agencies in caves and fissures, and are also derived from the debris of hard rocks disintegrated by frost, and spread out by water without rounding of the edges.

Grit is a rock composed of coarse sand or small stones, and is intermediate between the last rock and the next.

Sandstone is composed of grains of sand, more or less firm, and either angular or rounded, cemented together. When mixed with clay it becomes argillaceous sandstone. When cemented by carbonate of lime it is calcareous sandstone. Its grains are often superficially stained of red or brown colours by the oxide of iron. *Freestone* is a term applied to the softer and more easily worked sandstones; *Flagstone* to the laminated varieties. The harder varieties pass into *Quartzite*. *Greensand* is a variety coloured by grains of the hydrous silicate named glauconite. Sandstones with the surfaces of bedding and lamination covered with plates of mica are *micaceous* sandstones

Shale is hardened clay or mud having a laminated texture, due either to original deposition in layers or to subsequent pressure. On the one hand it passes into soft clay, on the other by metamorphism into slate. *Arenaceous shale* is mixed with fine sand and passes into sandstone. *Carbonaceous shale* is mixed and blackened with coaly matter. *Bituminous shale* or *Pyroschist* is impregnated with bituminous matter. *Calcareous shale* contains limestone in a fine state of division and effervesces with an acid. *Fireclay* is a soft variety rendered infusible by the absence of alkaline matter. It is often associated with beds of coal. *Kaolin* is a fine clay resulting from the decomposition of felspar. *Loess* is the alluvial mud deposited in lakes and rivers. *Loam* is a mixture of sand and clay.

Limestone includes all the unaltered rocks composed of calcium carbonate, or calcite. It is distinguished by its softness as compared with quartz and most of the silicious stones, and by effervescing with

an acid. It may be earthy, compact, crystalline, massive or laminated in structure; or with reference to matters mixed with it, argillaceous, bituminous, ferruginous, or cherty. *Oolite* is a variety composed of minute rounded concretions, which often show under the microscope a radiating prismatic structure as well as concentric lamination. *Travertin* or *Calcareous Tufa* is a limestone deposited by calcareous springs. *Stalactite* and *Stalagmite* are similar matter deposited on the roofs and floors of caverns. By mixture with fragments of limestone or of bone, Stalagmite may become a *calcareous* or *bone Breccia.*

Coral and *Shell Limestone* and *Crinoidal Limestone*, or more generally *Organic Limestones*, are composed of fragments of calcareous organisms, sometimes apparent to the eye, in other cases visible only under the microscope. *Chalk* is an organic limestone made up of tests of Foraminifera mixed with the minute organic bodies named Coccoliths.

Dolomite is a double calcium and magnesium carbonate. It may be distinguished from common limestones by its higher lustre, slightly greater weight, failure to effervesce with cold acid, and by often weathering of a rusty colour in consequence of the presence in it of ferrous carbonate.

Marl is an earthy mixture of calcium carbonate with clay or sand. The calcareous matter is sometimes in a fine state of division and sometimes as fragments of shells (shell-marl). Marl is distinguished from ordinary clay by effervescing briskly when treated with an acid.

Gypsum, or Calcium Sulphate, is of less common occurrence than limestone, but sometimes constitutes thick beds of great purity. *Anhydrite* is often associated with the ordinary hydrous variety.

Coal and carbonaceous rocks have already been referred to under the heading of Minerals.

Iron ores have also been noticed under the same heading.

Section 2. Metamorphic Rocks.

These are rocks originally aqueous or aqueo-igneous, which have been subjected to the action of heat and pressure, along with chemical agencies, until their particles have so rearranged themselves as to give a crystalline character accompanied by differences in the state of combination of the contained elements.

The metamorphic rocks are intermediate in character between the unaltered aqueous and the plutonic series. On the one hand they pass into ordinary aqueous rocks, on the other by becoming highly crystalline and losing their original bedding, they graduate into plutonic rocks. The principal varieties of these metamorphosed rocks are the following:—

Quartzite or *Quartz Rock* is a result of the alteration of sandstone whereby its grains of sand become inseparable and sometimes indistinguishable.

Gneiss is a product of the alteration of sediments, containing sufficient basic matter for the production of felspar and hornblende or mica. It thus resembles granite in composition, and is distinguished by its laminated structure and stratified arrangement. Many gneisses may have originally been bedded trachytes or volcanic tuffs.

Mica Schist is a crystalline mixture of quartz and mica. It is a product of the alteration of shales. It often contains disseminated minerals, as pyrite, garnet or chiastolite. By addition of felspar it passes into gneiss. By increase of quartz it becomes micaceous quartzite or quartz schist, and by diminution of its crystalline character it passes into Argillite.

Argillite or *Clay Slate* is a product of the alteration and hardening of clay or shale. It is remarkable for the development in it of *slaty structure*, which arises from the forcing by lateral pressure of all flat particles in a soft mass into positions in which they lie at right angles to the direction of pressure. In this way the most perfect lamination is often produced in planes quite different from those of bedding.

Hornblende Schist is a laminated mixture of hornblende with quartz, and sometimes with mica.

Talc Schist is a slaty rock in which talc takes the place of mica.

Chlorite Schist is a similar slaty rock consisting largely of that mineral.

Nacreous or *Hydro-mica Schist* is a name which has been given to crystalline slates in which a hydrous mica takes the place of the ordinary mica.

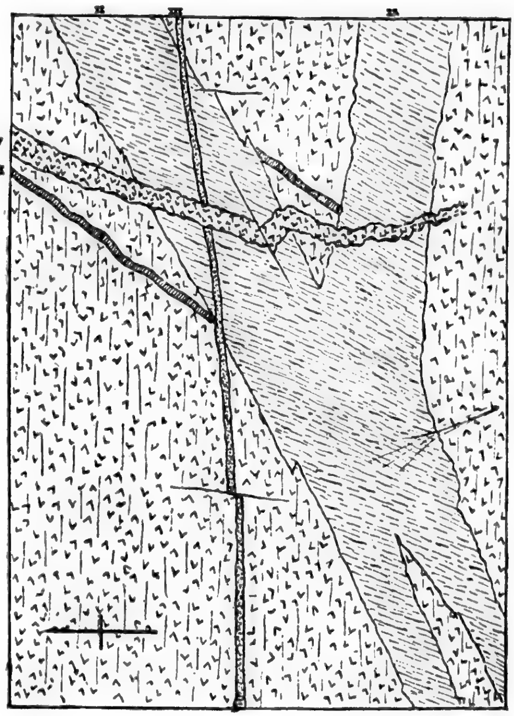
Marble or *Crystalline Limestone* and *Crystalline Dolomite* include the varieties of these rocks in which a perfect crystallization and often a white colour have been developed by metamorphism. *Ophiolite* is a marble containing grains or streaks and patches of serpentine.

Anthracite and *Graphite* result from the alteration of coal or of bituminous matter. Thus ordinary coal passes, under alteration, into anthracite, and finally, in certain cases, into graphite, and bituminous shales pass into graphitic slates.

Magnetite is very often a product of the metamorphism of ores consisting of the sesquioxide of iron.

Local metamorphism can often be observed at the contact of aqueous rocks with the larger igneous masses, and a study of these cases affords a key to the explanation of those larger examples in which no obvious cause of alteration is present. Metamorphism is induced or favoured by heat, by pressure, and by the percolation of heated and mineral waters; and rocks of complex character and containing basic and acidic minerals intermixed are those which present the most remarkable metamorphic

changes. Such rocks have abounded more especially in the oldest rock formations, and in those partly made up of igneous ejections. At the same time the older deposits and those nearest to igneous foci have been the most exposed to metamorphic agencies. Hence certain metamorphic or crystalline rocks are characteristic of the older formations though not absolutely confined to them.



Metamorphic rock (Gneiss) intersected by Igneous dykes. Lake of the Woods. (I) Red Felspar. (II) Greenish Diorite. (III) Hornblendic Diorite. (IV) Red Granite. (G. M. Dawson.)

Scale—6 feet to an inch.

II. STRATIGRAPHY.

1. Causes concerned in the Production of Rocks.

This and the four following sections may be regarded as intermediate in their character between Lithology and Stratigraphy, or as introductory to the latter.

In nature there is a constant struggle between aqueous and igneous agencies in modifying the materials of the earth's crust. The deeper portions of the crust are being slowly softened and crystallized under the influence of heat and pressure, and are thus being converted into metamorphic rocks, and these finally into plutonic masses, portions of which being erupted constitute volcanic products. On the other hand the waters and the atmosphere are constantly decomposing and wearing away the crystalline rocks at the surface, and depositing their detritus in the bottom of the waters. These processes seem to have been active throughout the whole of geological time in producing igneous and aqueous rocks. Since however the latter are the more important in geology, on account of their greater relative abundance, their regularly bedded character and the fossils they contain, we may direct our attention principally to them.

Atmospheric Erosion.—We have seen that the most common crystalline rocks are composed largely of silicates, as the Felspars, Hornblende and Pyroxene. When these are exposed to the action of the atmosphere and of rain water, which always holds carbon dioxide in solution, the soda, potash, lime, and other bases which they contain in combination with silica, are gradually removed in the state of carbonates, leaving the alumina and silica behind in an incoherent state. Thus from the decay of a hornblendic granite there may result quartz-sand, clay, limestone, and iron oxides, which when sorted and variously deposited by water, may assume the appearance of distinct alternating beds, while the alkaline matters removed in solution are washed into the sea or into lakes, where they may aid in chemical changes leading to other kinds of deposition.

To the atmospheric agencies we may also add the disintegrating power of frost, which by the expansion in the act of freezing of the water contained in rocks, chips off sand and fragments, and rapidly reduces very hard rocks to ruins. In mountains and the polar regions this action of frost is aided by the mechanical movement of glaciers, which removes to lower levels or into the sea the material disintegrated by frost, and which also exercises a polishing and abrading effect on the subjacent surface. The action of coast ice, which is also very powerful, may rather be classed with aqueous agencies.

Aqueous Erosion.—This takes place by the abrading action of rivers and torrents, by the beating of the waves on coasts, by tidal currents, by the action of cold heavy currents on the sea bottom, and by the solvent action of springs and other subterranean waters. As these agents are constantly at work, the changes which they produce in the lapse of ages are very great. It has been estimated that the atmospheric and aqueous causes of erosion at present in action, would suffice to remove the whole of the dry land into the sea in about six millions of years.

Deposition.—The materials thus set free by chemical decomposition and mechanical abrasion are deposited in layers in the depressed portions of the earth's crust occupied by the waters. The coarser materials, as pebbles and sand, may be thrown down along coasts and at the mouths of rivers; the finer materials will be carried farther out to sea, and those held in solution may be ultimately fixed in the organisms of coral animals and other marine creatures, and may form coral limestones and similar organic deposits.

In any given locality all these agencies, whether of erosion or of deposition, may be greatly modified from time to time by changes of level or of climate, whether arising from movements of the earth's crust, or from astronomical causes; and also by volcanic paroxysms breaking forth from time to time.

2. Hardening and Alteration of Aqueous Deposits.

Aqueous deposits thrown down by crystallisation may be hard from the first; but sedimentary beds are usually at first soft, and are hardened by subsequent processes, such as the following:—

(a) *By Pressure* of a great thickness of superincumbent material. In this way, for example, soft clay is hardened into

shale, and peat into brown coal; and there is reason to believe that lateral pressure, occasioned by folding and settlement of the earth's crust, may produce still more powerful effects in hardening and crystallizing rocks. Pressure may act by condensing soft sediments to a fraction of their original thickness, by arranging flat particles in the same plane, thus causing lamination or cleavage, by causing minute particles to adhere by contact and by developing heat.

(b) *By Infiltration* of mineral matter in solution. Subterranean waters usually contain calcium bicarbonate, soluble silicates or other mineral substances in solution, and depositing these in the interstices of sand, gravel, fragments of shells, &c., may ultimately cement such materials into a compact rock. (Fig. 1.)

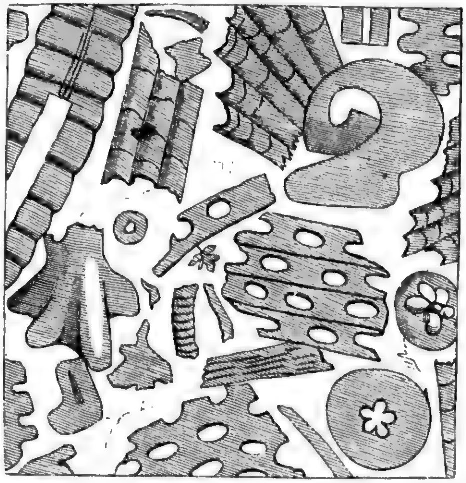


Fig. 1.—Fragment of Trenton Limestone, magnified. It is composed of broken pieces of corals, crinoids and shells cemented together by transparent calcite.

(c) *By Heat.* When sediments are buried to so great a depth that they are acted on by the earth's internal heat, or when heat is developed by the movement and crumpling of great masses of rock, or when sediments are invaded by intrusive molten rocks, they become baked and hardened, and in some cases their particles are enabled to arrange themselves as distinct crystalline

minerals or to enter into new chemical combinations. The result is metamorphism, which as already stated may change mud or volcanic ashes or similar incoherent material into the hardest and most crystalline rock. It is farther to be observed that the heat to which sediments are subjected at great depths, is not dry heat, since their substance is saturated with water, and this being prevented by pressure from escaping, remains in a heated state, and must greatly promote chemical and molecular changes.

3. Concretionary Action.

An important modification of these hardening processes results from concretionary action. This is an unequal hardening of the mass, whereby certain portions of it become indurated into balls, nodules or grains. It depends on molecular attractive movements collecting together certain constituents of the mass, and may produce the following kinds of concretionary structure :—

(*a*) The whole mass of material may assume a concretionary structure, aggregating itself into nodular grains. This is the case with *Oolitic limestones* and *Oolitic ores of iron*. A similar change sometimes occurs in the cooling of igneous masses. (Fig. 2.)

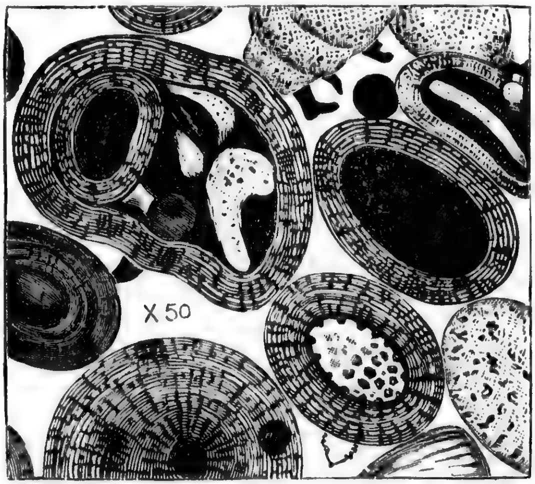


Fig. 2.—Magnified section of Oolitic Limestone (after Sorby), showing concretions with radiating and concentric structure, and some of them enclosing fragments of shells, &c.

(*b*) Foreign materials diffused through the mass may be collected into limited spaces, and thus form concretions. This is the case with *flints* in chalk and with *clay ironstone* in beds of shale.

(*c*) The cementing substance of the mass may be unequally collected in certain portions at the expense of the rest. This occurs in the hard concretions in clays and in "bull's-eyes" in sandstones.

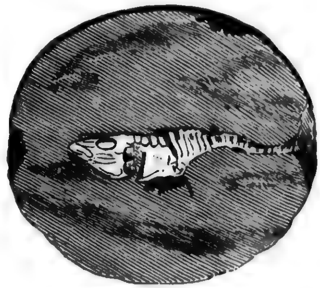


Fig. 3.—Rounded concretion containing a fossil fish, split open. Post-pliocene, Canada.

Any foreign body, as a fossil or a grain of sand, may form a nucleus for a concretion. (Fig. 3.) Concretions have often a concentric lamination marking their stages of increase. They are sometimes hardened at the surface while the interior remains soft, and the latter may subsequently crack from shrinkage. When these cracks are afterwards filled with other mineral matter, *septaria* concretions result. Concretions often assume very fantastic shapes, and have been mistaken for fossils.

Geodes, which are cavities in rocks lined with crystals, are distinct in their mode of formation from concretions, though sometimes confounded with them.

4. Colours of Aqueous Rocks.

The most abundant colouring matter in rocks is iron. Its monoxide and sulphide when diffused through sediments produce green, gray and blackish colours. Its sesquioxide produces red colours. Its hydrous sesquioxide gives yellow, buff and brown shades. Peroxide of manganese is sometimes a cause of black colours in rocks, and coaly matter is also a not infrequent cause of the blackening of sediments.

The following facts are important with reference to the colours produced by iron :—

(*a*) In the subaerial decomposition of most rocks a sufficient quantity of sesquioxide of iron is produced to colour the resulting sands or clays. In ordinary circumstances it is the brown or hydrous oxide that is produced in this way; but in warm climates, under the influence of volcanic heat and in the presence of saline waters, the red oxide is produced. Thus the subaerial decomposition of crystalline rocks coloured gray, green or black by sulphide or monoxide of iron, gives rise to brown and red sediments.

(*b*) If the sediments thus coloured are rapidly washed down and deposited in the sea, or in limited areas of fresh or salt water, they may retain their colours, and thus the red, brown and purple sandstones and clays so characteristic of certain formations are produced.

(*c*) If the sediment is long abraded by moving water, the clay is separated from the sand, and the superficial red coating is washed from the latter so that it loses its colour. In this way gray or white sandstones are often found to alternate with red or reddish shales.

(*d*) When sediments coloured with iron are deposited in fresh water along with organic matter, as peat, &c., the latter deprives the iron of a portion of its oxygen, reducing it to monoxide, and this being soluble in the acids naturally produced by the decay of the vegetable matter, is removed, leaving the sand or clay in a bleached condition.

(*e*) When the deoxidising process occurs in sea water, the sulphates present in the latter being decomposed at the same time with the iron oxides, a black iron sulphide is produced, which gives a gray colour more or less dark to the sediment. Material coloured in this way becomes buff or brown on weathering, and becomes red when heated in the air. This is a useful mark of marine clays. In this case or the last, scattered organic fragments deposited in red sediments and not in sufficient quantity to affect the colour of the whole, produce gray or white stains.

(*f*) If organic matter be present in large quantity, it not only removes the red colour but communicates its own black or dark brown colours to the whole.

The above considerations serve to show why red rocks have

been deposited in large quantity in times of physical disturbance and volcanic activity, and generally when deposition is rapid and organic matter absent. They also serve to explain the presence of red beds with rock salt deposited from the waters of saline lakes or lagoons. They also explain the rarity of fossils in red rocks, since the retaining of the red colour implies scarcity of organic remains, and an excess of peroxide of iron tends to oxidise and destroy such as may be present. On the other hand they show why gray and dark coloured beds are those which most abound in fossils.

5. Markings on the Surfaces of Aqueous Rocks.

The circumstances under which aqueous beds have been deposited are often indicated by the markings seen on their surfaces.

(a) *Ripple marks*, caused by the motion of currents throwing up slight ridges and hollows at right angles to the direction of the current.

(b) *Current lines*, caused by the driftage of sand, organic fragments, or sea-weeds and drift wood, in the direction of the current.

(c) *Rill marks*, caused by the running of drainage water over inclined surfaces of mud and clay after recession of the tide. These are often so complicated as to simulate foliage.

(d) *Shrinkage cracks*, produced by the drying and shrinkage of muddy surfaces when left bare to be acted on by the sun and air.

(e) *Rain marks*, or rounded pits produced by rain drops, or washed surfaces produced by continuous rain, afterward covered up and preserved by subsequent deposits. (See figures at end.)

These markings belong for the most part to shallow water and to the vicinity of the shore and to tidal estuaries. They are often of much interest as indicating the conditions of deposit and the changes which have taken place in these.

6. Arrangement of Rocks on the Large Scale.

With reference to this, the materials of the earth's crust exist in three different conditions:—(1) *The Stratified;* (2) *The Massive or Unstratified;* (3) *The Vein-formed.* The rocks of the second and third classes are however subordinate to those of the first, which vastly predominate in those parts of the earth open to our inspection. We may therefore consider first and principally the Stratified rocks. (Fig. 4).

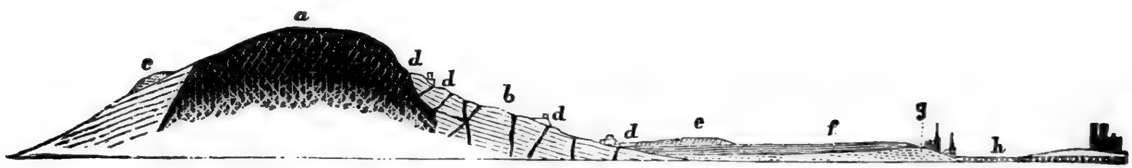


Fig. 4.—Section through Montreal mountain, showing massive igneous rock at (*a*); dykes at (*dd*); and bedded or stratified rocks at (*b, e, f g*). The lower of the latter belong to the Siluro-cambrian age, the upper (*e, f g*) to the much later Pleistocene formation.

All ordinary aqueous or sedimentary rocks are stratified, or arranged in beds more or less nearly, when undisturbed, approaching to a horizontal position.

A Lamina or *Layer* is the thinnest sheet into which a stratified rock is divisible.

A Stratum or *Bed* is of greater thickness, or may consist of several laminæ—*e. g.* a bed of laminated sandstone consisting of several layers.

A Formation consists of several beds deposited consecutively and under similar general conditions. A formation may thus include beds of rock of different kinds, though usually there is a certain lithological similarity in the beds constituting a formation—*e. g.* the coal formation, which includes many beds of sandstone, shale, coal, &c. (Fig. 5.)

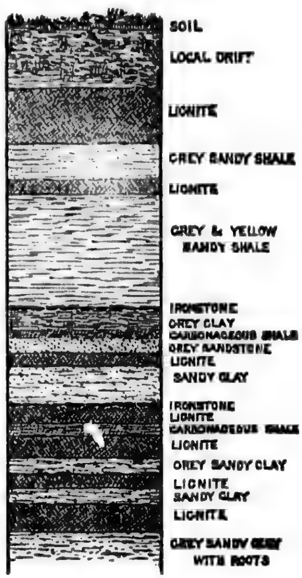


Fig. 5.—Section of Lignite Tertiary formation, west of Manitoba. The whole of the beds shown, except the soil and drift, belong to one formation, though differing in mineral characters. Some of them, as the shale beds, are laminated. (G. M. Dawson.)

A System or *Group of Formations* includes all the formations of one of the larger geological periods—*e. g.* the carboniferous system, which includes with the coal formation other formations belonging to the same great geological period.

Inasmuch as formations and systems of formations imply the lapse of time, they may also be designated by terms relating to time. Thus we may speak of the carboniferous period, the coal-formation epoch.

The term *Seam* is often used by miners for beds of useful minerals; and when such beds are considerably inclined, they are sometimes called veins, though not of the nature of true veins.

7. Joints and Slaty Cleavage.

These appearances are important, because it is necessary to distinguish them from planes of bedding.

Joints are planes of division cutting beds at various angles, though usually approaching to vertical. They often divide the bed into oblique-angled blocks by the intersection of two sets of cleavage planes; and when the cleavage planes of one set are close together they often simulate true bedding. Joints sometimes facilitate the operations of the quarryman by enabling blocks of stone to be more readily detached; but when numerous they injure stones otherwise useful.

When joints occur in beds of igneous rock they sometimes give origin to a *columnar structure*, as in beds of basalt.

Joints are often *slickensided*, that is they have their surfaces polished by friction which has occurred during movements of the beds.

Joints are sometimes widened into fissures, which being filled with foreign matter, constitute veins. The joints of rocks thus connect themselves with the vein-condition afterwards to be noticed.

Jointed structure sometimes weakens otherwise enduring rocks so as to permit them to be worn into ravines and valleys.

Slaty structure is a lamination not caused by original deposition but by pressure subsequently exercised, whereby plates of mica and other flat bodies present in the material, may be induced to assume positions parallel to the plane of pressure. Such slaty structure or slaty cleavage has been effected in many regions over

great thicknesses of beds, and while it is of practical importance as giving the best roofing slates, it is somewhat puzzling to geologists as masking the true bedding. This can however usually be ascertained by noticing the bands of colour and structure which represent the original planes of deposit. In some cases the planes of bedding and of cleavage coincide, but in very many they are altogether different.

8. Inclined Position of Beds.

Aqueous strata have been originally deposited in a position approaching to horizontality. The only exceptions to this are where these beds have been uniformly disposed over uneven or inclined surfaces, or where material has been washed over the edge of a bank, giving rise to oblique stratification or false bedding. Movements of the crust of the earth, and especially movements of folding or bending which have apparently arisen from the shrinkage of the mass of the earth as compared with its crust, have however caused the originally horizontal beds to assume various degrees of inclination. Aqueous erosion has further caused the broken edges of bent strata to protrude at the surface. The degree and direction of such inclination afford most valuable data for ascertaining the relative positions and ages of beds. The most important facts of this kind are the following:— (Fig. 6.)

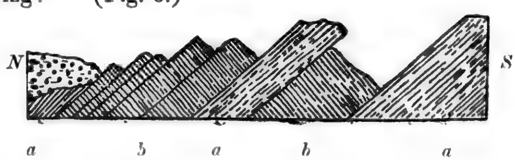


Fig. 6.—Inclined position of rocks. Beds of slate (*a*), and iron ore (*b*) dipping to the northward at an angle of 41°.

(a) *Dip*, or the angle of inclination to the horizon as measured by the clinometer.

(b) *Direction of dip* as ascertained by the compass.

(c) *Strike*, or the horizontal line at right angles to the dip.

(d) *Outcrop*, or the line of intersection of the plane of the bed with the surface of the country. On perfectly level ground this is of course identical with the strike. Otherwise it is different.

Observations of these facts can be made in natural exposures, as cliffs, shores, &c., in artificial exposures, as quarries, cuttings, mines, &c. The harder rocks usually project in ridges and the softer are cut into hollows. Hence the lines of ridges and valleys often form very useful guides in tracing the outcrops of beds. The harder rocks are also more likely to crop out at the surface than those which are softer, and the latter are more liable to lie in low ground and to be covered with soil.

A line drawn across the strike of a series of beds gives a section of those beds, and in proceeding along such a line in the direction toward which the beds dip we obtain an *ascending series*. In the opposite direction we obtain a *descending series*. Thus we can ascend or descend geologically in proceeding along the surface of the ground, and geological ascent and descent do not coincide with topographical, except where the beds are horizontal or nearly so.

The thickness of beds is always measured at right angles to their dip. For ordinary purposes it may be assumed that the thickness is equal to $\frac{1}{12}$ of the distance across the outcrop at 5° of inclination, and so on for every additional 5°.

When we follow a series of beds in ascending or descending order, we at length arrive at a line in which their dip changes to the opposite direction. When this takes place in the descending series it constitutes an *anticlinal line* or *axis*, sometimes called an *anticline*. When it takes place in the ascending series it constitutes a *synclinal line* or *syncline*.

When the anticlinal and synclinal axes are not horizontal, or when the surface of the country is inclined, the beds may be seen at the surface to bend around the ends of the anticlinals or synclinals, so that on a map these appear as more or less abrupt bends or loops of the strata.

In those regions where the beds have been slightly inclined, the anticlinals and synclinals are low and wide; but in disturbed districts the folds are often very abrupt, causing the beds to approach to verticality, and in some places to be overturned. In such cases also the anticlinals or synclinals are sometimes very steep on one side and less so on the other, and they are not infrequently accompanied with minor flexures and foldings of the beds as well as with fractures or dislocations. In such disturbed districts great caution is requisite lest abruptly folded and re-

peated beds should be regarded as constituting a continuous series, and lest overturned beds should be regarded as in their natural positions. (Figs. 7, 8, 9.)

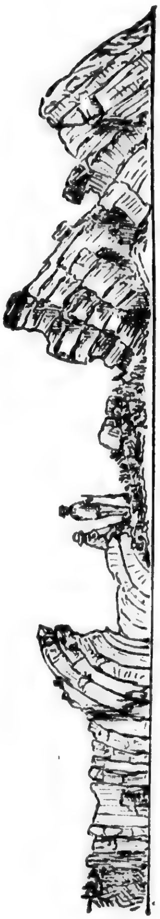


Fig. 7.—Anticlinal fold, Lignite Tertiary formation, showing also denudation of the axis of the anticlinal, St. Mary River, N. W. T. (After G. M. Dawson.)

Fig. 8.—Contorted Laurentian rocks, Ottawa River. (After Logan.) (*a*, *b*) Lower Laurentian Gneiss and Limestone. (*c*) Upper Laurentian. (*d*) Mass of Granite. (*e*) Dyke of Porphyry.

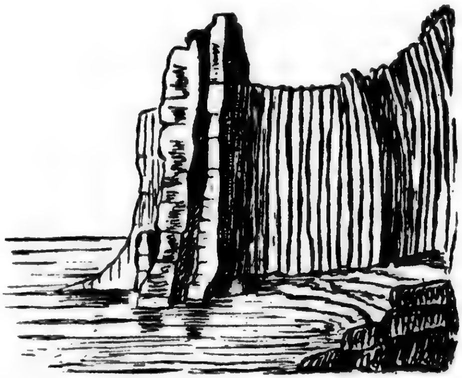


Fig. 9.—Beds of Limestone, Sandstone and Shale of Lower Carboniferous age in a vertical position. Smith's Island, Cape Breton.

9. Faults.

When movements of beds have been accompanied with fracture and slipping of the beds up or down, faulting or discontinuity of beds is produced.

Faults traversing inclined beds may displace them laterally as well as vertically. The vertical displacement is sometimes designated by the term slide, the lateral displacement by the term heave. A *downthrow* is said to take place on that side toward which the beds are sunken, and an *upthrow* on that side toward which they have risen. When the plane of a fault is inclined, the inclination is usually called by miners its "*hade*," and is measured from a vertical plane. The downthrow is almost always found to have occurred on the side toward which the plane of fault inclines. When the contrary occurs the fault is said to be reversed. This fact is often of great importance in estimating the effects of faults. (Fig. 10.)

In observing faults, the facts to be noticed are the directions of the planes of fracture, their hade and the amount and direction of movement, with its effect on the beds traversed. When these facts are obtained, all the effects of the dislocation can be readily worked out, though, when several lines of fault cross the same beds, the appearances are often very deceptive, leading to incorrect estimates of the thickness and number of the beds.

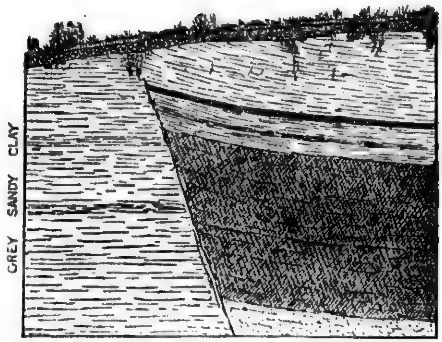


Fig. 10.—Fault, Lignite Tertiary series, Porcupine Creek, N. W. T. (G. M. Dawson.) The bed of lignite (*a*) has been thrown down, and has been removed by denudation from the other side of the fault.

As the inequalities caused by faulting have usually been rounded or smoothed off, and the line of a fault is often a weak place where the rocks have been worn down and covered with debris, faults can very rarely be distinctly seen, and their nature and direction can usually be ascertained only by inference from the dislocation observed in the beds on their opposite sides. They are very numerous in disturbed districts, and there are often two or more sets of them crossing the beds in different directions. In most cases, however, the amount of movement which they produce is not great.

10. Unconformability.

When one series of beds has been disturbed and another deposited upon the upturned edges of the first, the upper series is said to rest unconformably on the lower. This indicates not merely a difference of age but an interval of time between the dates of the two series. It often happens also that the edges

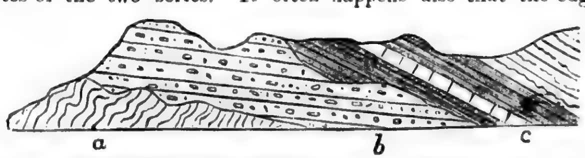


Fig. 11.—Unconformable superposition of (*c*) Silurian beds on (*b*) Cambrian, and of the latter on (*a*) Eozoic. West of Scotland. (After Murchison.)

of the lower series show evidences of great erosion, or that the beds of the lower series have been hardened and altered before the deposition of the upper. A false or simulated want of conformity occurs when a bed has been cut unequally by water before the next bed is deposited. When congl merates or coarse sandstones rest upon finer beds such apparent unconformity is often produced. (Fig. 11.)

11. Denudation.

This is the removal of matter by atmospheric or aqueous erosion. It has already been referred to as a source of the materials of aqueous deposits. We must now consider it as concerned in giving relief to the surface of the earth. That denudation has taken place to a great extent may be inferred from such facts as the following: The projection of hard beds and massive rocks in consequence of the removal of softer material from around them; the existence of synclinal elevations in consequence of the erosion of anticlinals which once were higher but must have been more perishable owing to their fissured condition; the planing away to a low level of rocks which testify by their dips or by the existence of extensive faults that they once rose to much greater height and were very uneven; the cutting of deep ravines through table lands, and the quantity of stones, gravel, sand, and other detritus of older formations, employed in the building up of those which are newer. (Fig. 12.)

Fig. 12.—Denudation of horizontal beds, Great Valley, N. W. T. (G. M. Dawson.)

Geological observation has shown that the inequalities of the earth's surface are due to denudation more than to any other cause.

It has been estimated that the areas drained by the rivers of our continents are losing by denudation at rates varying from 1 foot in 1500 years to 1 foot in 6000 years. At these rates, were no counteracting elevation to take place, our continents would be levelled with the sea in from four millions to nine millions of years.

12. Massive Rocks.

These are in almost all cases of igneons origin, and can be readily distinguished both by their mineral character and their mode of occurrence, from the stratified rocks. Such irregular masses may represent either (1) the remains of the bases of old volcanic cones, the looser parts of which have been swept away; or (2) exotic or intrusive materials ejected among other rocks from beneath; or (3) portions of the aqueous crust so much altered that their stratification has been obliterated.

If the stratified rocks have been altered at their contact with igneous masses, or are penetrated by veins proceeding from them, we know that the masses are newer than the beds. On the other hand, if the massive rocks have been eroded before the deposition of the beds, if the latter are unaltered, and if they contain debris derived from the massive rocks, we know that these are older. (Fig. 4.)

13. Vein-formed Rocks.

The most common veins are fissures filled with material introduced either in a molten state or in aqueous solution.

Igneous veins or *dykes* are often of great size, and extend through the stratified rocks for long distances. They are filled with some of the kinds of igneous rock; sometimes present a jointed structure at right angles to their sides; often have the surface in contact with the adjacent rock of different texture from the interior; and have often, by their heat, produced considerable alteration in the adjacent rock. They are especially numerous in the vicinity of igneous masses and of volcanic foci ancient or modern. (Fig. 13.)

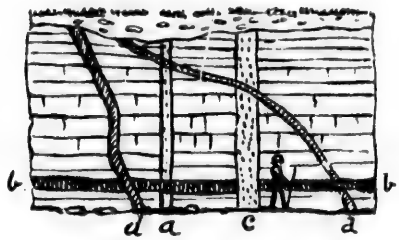


Fig. 13.—Igneous dykes or veins, extension reservoir, Montreal. (*a*) Felspathic dyke traversing beds of limestone. (*b*) Floor or horizontal vein of Dolerite cutting (*a*). (*c*) Thick dyke of Felsite cutting (*b*). (*d*) Inclined dykes of Dolerite cutting all the others.

Aqueous veins, which are also often *mineral veins,* are usually filled with crystalline minerals deposited in them by water. They often present a laminated appearance, owing to the deposition of successive coats of matter in the walls of the vein. Occasionally the walls of veins present margins or "*selvages*" consisting of decomposed rock or decomposed veinstone.

In the case of mineral veins, the mass filling the vein is called gangue or veinstone, as distinguished from the ore associated with it. (Fig. 14.)

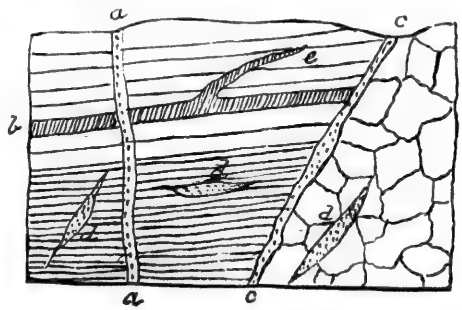


Fig. 14.—Metallic veins near the contact of slate and granite. (After Von Cotta.) (*a*) Fissure vein. (*b*) Horizontal or bedded vein sending off a branch (*e*). (*c*) Contact vein at the junction of the two formations. (*d*) Lenticular or interrupted veins, sometimes called by miners "pockets."

Veins are often very irregular in their forms. This arises not only from the original irregularity of cracks traversing rocks, but from subsequent shifts of the containing walls, from the de-

tachment of loose pieces or "*horses*" from the sides, and from erosion of the walls by subterranean waters. They also differ very much in their contents in passing from one kind of rock into another, and are often decomposed and changed by atmospheric action at their outcrops.

There is reason to believe that some veins have been filled simultaneously with their opening, so that they have never actually been open fissures. Such veins, which present many peculiar appearances, are called segregation veins.

14. Chronology of Beds.

Superposition.—The great leading fact as to the ages of aqueous deposits is that the upper of two beds is necessarily the newer. Wherever therefore the actual superposition of beds can be ascertained, there can be no doubt as to their relative ages. In mines and borings, and in cliffs and quarries, we can thus easily ascertain the ages of the beds exposed. In the case of inclined beds this is equally obvious as in those which are horizontal. In these however we must be careful not to be misled by overturns and by beds repeated by faults.

No one exposure, however, can show anything more than a limited portion of the series of rocks occurring in any district of considerable extent. Hence in extending the results of our observations it is necessary to have recourse to other data.

Tracing of beds.—Having ascertained the sequence of beds in one locality, we endeavour to trace them along their outcrops. We thus bring them into relation with other beds not seen in the original exposure.

Mineral character.—Where the tracing of the beds fails, we have to compare them in different sections, and to endeavour to recognize them by their mineral character—a succession of like beds in two not very distant sections giving us fair evidence of identity. Here however we must remember that in tracing any given bed for a long distance, it cannot be expected to retain precisely the same character, but may be represented by some different material.

Fossil remains.—When we can obtain from any of the beds in question fossil organic remains, these afford us a new means of testing identity of age. Experience has shown that in the course of the earth's history the facies of animal and vegetable life has been constantly changing, so that the fossils of one for-

mation are different from those of another. When we have in any one locality ascertained this succession, we are safe in applying it to others. The evidence of fossils is thus at present held to be one of the best criteria for the ages of stratified rocks.

In employing fossils as evidence of age, we have however to bear in mind certain necessary precautions. There are other differences than those of age; as for example, the difference between animals of the sea, of freshwater and of the land; of different depths in the sea, and of different climates. It is necessary, therefore, to compare animals or plants of like habitat and conditions of existence. It is farther to be observed that certain forms of life have been of longer duration in geological time than others, and therefore do not so definitely mark the lapse of time. Again, certain forms of animal or vegetable life may have begun earlier or continued later in one locality than in others. On these acccounts the evidence of fossils is more certain with reference to the greater geological periods than with reference to the minor subdivisions of these.

15. Geological Maps and Sections.

The facts and generalizations obtained on the above grounds are represented to the eye on maps and sections. On the former are indicated by spots or lines of colour or by differences of shading the different formations and their precise boundaries as far as ascertained. To these may be added marks indicating dip and strike and other arrangements. (Fig. 15.)

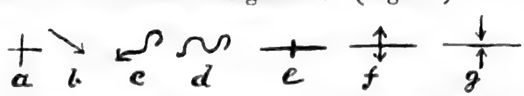


Fig. 15.—Marks used in mapping. (*a*) Horizontal beds. (*b*) Inclined. (*c*) Undulating. (*d*) Contorted. (*e*) Vertical. (*f*) Anticlinal. (*g*) Synclinal.

While maps exhibit the horizontal distribution of formations, sections show more clearly the relations of age and superposition. Lines of section observed on the ground may in the first instance afford materials for the construction of a map, and when a map has been drawn these lines may be marked on it, and the sections along these lines may be drawn to accompany it. Such sections are usually named horizontal sections. But vertical sections may be obtained in shafts and borings, or may be constructed with the aid of the horizontal sections.

III. PALÆONTOLOGY.

1. Preservation of Organic Remains.

This depends in the first instance on the accidental imbedding of animals and plants or of portions of them, in deposits in process of formation, or on the accumulation of remains of animals and plants on the surfaces on which they live, as for example of shells and corals on the sea bottom, or of vegetable matter in bogs and swamps. In one or other of these ways most aqueous deposits become more or less charged with organic remains. These are sometimes entire and sometimes fragmentary, and as already stated some beds contain so great abundance of organic fragments that they may be regarded as organic rocks. Often, however, the presence of organic fragments can be detected only by the lens or the microscope. (Figs. 16, 17.)

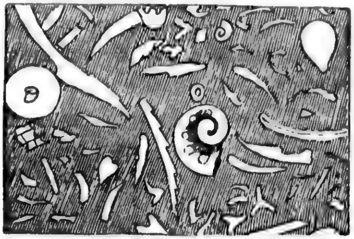


Fig. 16.—Fine grained Trenton limestone, Montreal, showing organic fragments × 10.

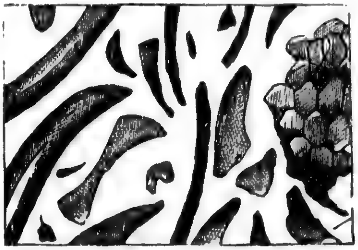


Fig. 17.—Chazy Limestone, Island of Montreal, showing fragments of shells and Stenopora × 10.

Organic remains may occur in an unchanged condition or only more or less altered by decay. This is often the case with such enduring substances as shells, corals, bones and wood, especially in the more recent deposits, in which such remains occur little modified or perhaps only slightly changed by partial decay of their more perishable parts, as for instance of the animal matter of bones. In the older formations, however, organic remains are usually found in a more or less mineralized condition, in which their original substance has been wholly or in part replaced by mineral matter, or has been chemically changed. The more important of these changes are the following:—

(a) *Infiltration* of mineral matter which has penetrated the pores of the fossil in a state of solution. Thus the pores of fossil wood are often filled with calcite, quartz, oxide of iron or sulphide of iron, while the woody walls of the cells and vessels remain in a carbonized state. (Fig. 18.) Bones, shells and corals in like manner have their cavities filled with mineral matter, and are rendered hard and heavy thereby. In the sea bottom the filling material is not infrequently composed of Glauconite or other hydrous silicates. (Fig. 19.) We sometimes find on microscopic examination that even cavities so small as those of vegetable cells and vessels have been filled with successive coats of different kinds of mineral matter.

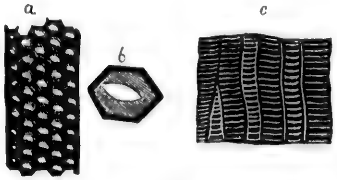


Fig. 18.—Discigerus tissue (*a*, *b*), and Scalariform tissue (*c*) from carbonized plants of the Devonian system, highly magnified.

(b) Organic matters may be entirely *replaced* by mineral substances. In this case the cavities and pores have been first filled, and then, the walls or solid parts being removed by decay or solution, mineral matter either similar to that filling the cavities or differing in colour or composition, has been introduced. Silicified wood and silicified corals often occur in this condition. In the case of corals and similar calcareous structures included in limestone, it sometimes happens that the walls of the corals are

silicified while the cells are filled with limestone. Fossils thus preserved often appear with great distinctness projecting from the weathered surfaces of the containing rock. (Fig. 20.) In the case of silicified wood, it sometimes happens that the cavities of the fibres have been filled with silica and the wood has been afterwards removed by decay, leaving the casts of the tubular fibres as a loose filamentous substance. The more important of the foregoing modes of preservation are represented in Fig. 21.

Fig. 19.—Joint of a Crinoid having the pores filled with a hydrous silicate allied to Glauconite. Upper Silurian, New Brunswick. Magnified.

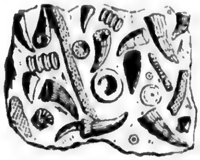


Fig. 20.

Fig. 20.—Silicified corals, *Petraia pygmea*, and crinoidal joints weathered out on a rock surface. (After Billings.)

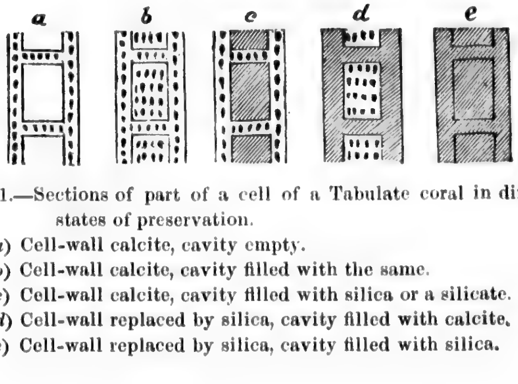


Fig. 21.—Sections of part of a cell of a Tabulate coral in different states of preservation.

(*a*) Cell-wall calcite, cavity empty.
(*b*) Cell-wall calcite, cavity filled with the same.
(*c*) Cell-wall calcite, cavity filled with silica or a silicate.
(*d*) Cell-wall replaced by silica, cavity filled with calcite.
(*e*) Cell-wall replaced by silica, cavity filled with silica.

(c) The substance of organic remains may be wholly removed, leaving mere *moulds* or *impressions* of their external forms, or perhaps moulds of the external forms and casts of the interiors. This frequently occurs on the surfaces of rocks, where for example calcareous fossils have been weathered out from a harder matrix, but it also occurs in the interior of porous beds, owing to the solution of the fossils by percolating waters. In the case of fossils in this state, it is always necessary to consider whether the impression observed is that of the true exterior surface, of an inner layer, or of an interior cavity.

Fig. 22.

(d) The cavities left by fossils which have decayed may be filled with clay, sand or other foreign matter, and this becoming subsequently hardened into stone may constitute a *cast* of the fossils. Trunks of trees, roots, &c., are often preserved in this way, appearing as stony casts, often with the outer bark of the plant forming a carbonaceous coating on their surfaces. (Fig. 22.)

Fig. 22.—Trunk of Sigillaria represented by a sandstone cast of the interior of the bark. Coal formation of Nova Scotia. Reduced.

Fossils preserved in the two first modes usually show more or less of their minute structures under the microscope. These may be observed, (1) By breaking off small splinters or flakes and examining them either as opaque or as transparent objects. (2) By treating the material with acids, so as to dissolve out the mineral matters or portions of them. This method is applicable to some fossil woods, silicified corals, &c. (3) By grinding thin sections. These are first polished on one face, then attached to glass slips by a transparent cement or Canada balsam, and ground until they become so thin as to be translucent.

Ichnites or fossil footprints and similar markings constitute a peculiar and sometimes interesting kind of fossils. Animals walking over muddy shores may leave impressions, which being partially hardened by the air and sun, may not be obliterated by the succeeding deposits of sand or mud. Once so covered up, they remain for an indefinite time, and if the beds be har-

dened into stone, the footprints appear distinctly as the layers are removed by the quarrymen. In this way the footprints of some land animals, not known to us by other remains, have been preserved, and important information has been obtained as to their affinities and habits. (Fig. 23.)

Fig. 23.—Footprints of a Batrachian (*Sauropus*). Coal-field of Cape Breton.

Not only land animals, but aquatic creatures, as fishes, crustaceans, worms, and mollusks, have left impressions and trails on the surfaces of beds, and these though less definite than the footprints of land animals, are of some importance as fossils. Such impressions have sometimes been mistaken for fossil plants; but they can be distinguished by the absence of carbonaceous matter, by their close connection with the substance of the containing beds, by their being in relief on the under side of the beds, and by their forms. (Fig. 24.)

The geological observer in examining any section or exposure of rocks, while noting all the facts respecting stratigraphical arrangement and relations, carefully collects the fossils of each bed, and labels them in such a manner that their order of succession can be preserved. The study of these fossils may be expected to afford important information respecting the age and conditions of deposition of the beds. Should the observer not

possess the special knowledge necessary to interpret the fossils obtained, he has recourse to palæontological specialists, either experienced in the fossils of the formation in question, or of the groups of animals or plants represented in the collections.

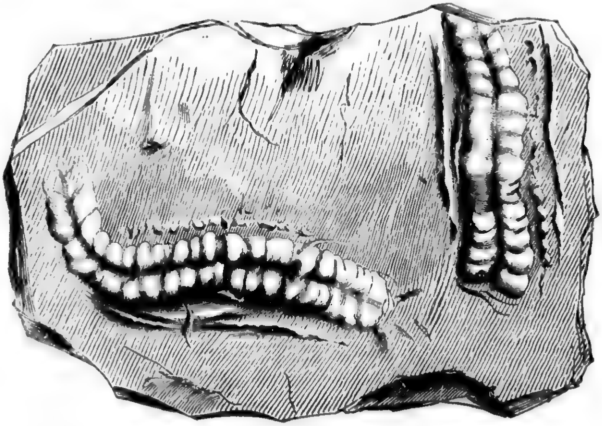


Fig. 24.—Tracks probably of a Crustacean (*Rusichnites*). Coal-formation of Cape Breton.

The most abundant and characteristic fossils available to the palæontologist are those of aquatic animals, having hard shells, crusts or cells. Thus practically the most important elementary knowledge of the study of fossils is that relating to the characters of invertebrate animals, and especially those of the sea. The student should therefore have some familiarity with this subject, and should have for reference some good zoological text-book, and if possible some work on the special palæontology of the districts or formations he is studying.

In some geological formations, especially the middle and newer members of the geological series, a knowledge of vertebrate animals becomes important; while in others, as the coal-formation, an acquaintance with fossil plants is necessary.

The following tables indicate the groups of animals and plants most important to be known in connection with the study of fossils:—

2. Classes of Animals most important in Palæontology.

Sub-kingdom	Division	Class	Examples
Radiata	*Protozoa*	1. Rhizopods	Foraminifera, Polycistina.
		2. Porifera	Sponges.
	Coelenterata	3. Hydrozoa	Graptolites, Sertularians, &c.
		4. Anthozoa	Coral animals.
	Echinodermata	5. Echinodermata	Crinoids, Star-fishes, Sea-urchins.
Mollusca		6. Polyzoa	Sea mats, &c.
		7. Brachiopoda	Lamp-shells, &c.
		8. Lamellibranchiata	Ordinary bivalves.
		9. Gasteropoda	Snails and their allies.
		10. Cephalopoda	Nautili, Cuttlefishes, &c.
Articulata	*Vermes*	11. Annelida	Worms.
	Arthropoda	12. Crustacea	Soft shell fishes, &c.
		13. Insecta	Insects proper and Myriapods.
		14. Arachnida	Spiders and Scorpions.
Vertebrata		15. Pisces	Fishes.
		16. Batrachia or Amphibia	Frogs, Newts, &c.
		17. Reptilia	Reptiles proper.
		18. Aves	Birds.
		19. Mammalia	Mammals.

3. Classification of Plants for purposes of Palæontology.

Cryptogams	*Thallogens*	Algæ	Sea weeds.
		Lichenes	Lichens, &c.
		Fungi	Mushrooms, &c.
	Anogens	Musci	Mosses.
		Hepaticæ	Liverworts.
	Acrogens	Filices	Ferns.
		Lycopodiaceæ	Club-mosses.
		Equiseta	Mares-tails.
Phaenogams	*Gymnosperms*	Cycadeæ	Cycads.
		Coniferæ	Pines, &c.
	Angiosperms	Numerous families of exogenous and covered-seeded plants.	
	Endogens	Numerous families of palms, grasses, and allied plants.	

IV. HISTORICAL GEOLOGY.

The application of the facts and principles of lithology, stratigraphy and palæontology to any given district, enables us to work out the geological succession of formations or geological history of the district in question, including not only the physical changes but the changes in living beings that may have occurred. The comparison and grouping of such local results enables us at length to frame a table or chart of the geological history of the whole earth. This we shall now proceed to construct, beginning with the oldest formations, and giving what may be regarded as typical examples of each from those regions in which it may be best developed and most fully studied.

The whole geological history of the earth may be included in four great Periods, the names of which have been based on the progress of animal life. They are, beginning with the oldest—

1. *The Eozoic Period*, or that of Protozoa.
2. *The Palæozoic Period*, or that of Invertebrate animals.
3. *The Mesozoic Period*, or that of Reptiles.
4. *The Kainozoic Period*, or that of Mammals and of Man.

They are farther subdivided into *Ages*, or if we regard the rocks themselves rather than the time occupied in their deposition, into *Systems of Formations*. These are represented in the following table, beginning as before with the oldest:

EOZOIC	Laurentian. Huronian.
PALÆOZOIC ...	Cambrian. Siluro-Cambrian. Silurian. Erian or Devonian. Carboniferous. Permian.
MESOZOIC	Triassic. Jurassic. Cretaceous.
KAINOZOIC ...	Eocene. Miocene. Pliocene. Pleistocene. Modern.

In noticing these systems of formations and their subdivisions in detail, we shall begin as far as possible with Canadian representatives of them, and shall then notice their foreign equivalents and characteristic fossils; concluding the notice of each system with a statement of its geographical distribution. Since Canada embraces about half the area of North America, and includes portions of all the geological formations of the continent, we shall in most cases be able to obtain within its limits typical examples of rocks and fossils; and when these fail, shall have recourse to other regions.

EOZOIC PERIOD.

I. Laurentian System.

1. *Lower Laurentian.* In Canada—Orthoclase gneiss of Trembling Mountain (Logan), Ottawa gneiss (Geol. Survey), lower part of Lower Laurentian of Logan. European equivalents—Bogian gneiss, Ur gneiss, Lewisian gneiss. Consists mostly so far as known of beds of orthoclase gneiss destitute of fossils, constituting the "fundamental gneiss" of some geologists.

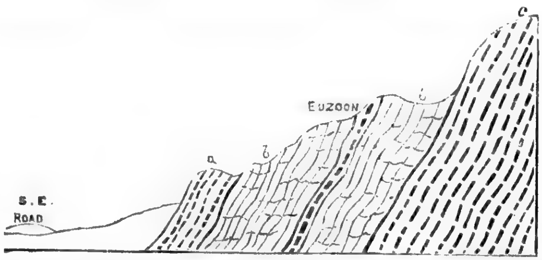


Fig. 25.—Section showing the mode of occurrence of *Eozoon* in Middle Laurentian at St. Pierre. (*a*) Gneiss; (*b*) Limestone; (*c*) Diorite and Gneiss.

2. *Middle Laurentian.* In Canada—Gneiss, diorite, limestone, pyroxene rock, &c., of Grenville, Petite Nation, &c., being the upper part of the Lower Laurentian of Logan. European equivalents—Ur gneiss in part, Lewisian gneiss in part, Etage A of Bohemia in part, Dimetian of Wales? Gneiss and crystalline limestone of Brittany.

Fossils.—Eozoon Canadense, and graphitised plants. (Figures of many of the fossils named in this and following pages will be found in the plates at the end.)

3. *Upper Laurentian.* In Canada—Labradorite and Anorthosite series of the Ottawa district, &c. European equivalents—Etage A of Bohemia in part, Dimetian of Wales? Norite formation of Scandinavia. No fossils known.

Distribution in Canada, &c. These formations constitute an extensive angular belt extending south-westward, north of the St. Lawrence valley, from Labrador to the Western coast of Lake Superior and thence north-west to the Arctic ocean. At the Thousand Islands this belt is connected with an extensive peninsula in the State of New York. Minor areas protrude through the Palæozoic rocks in Newfoundland, New Brunswick, and the Atlantic coast of the United States, and also probably in the mountainous belt fringing the Pacific coast. Iron ores, Apatite and Graphite abound in the Laurentian.

II. Huronian System.

1. *Lower Huronian.* In Canada—Chloritic slate, jasper conglomerate, slate conglomerate, quartzite, limestone and bedded diorite of Georgian Bay. Similar rocks in Newfoundland, New Brunswick and possibly also in the Eastern Townships of Quebec. European equivalents — Urschiefer of Scandinavia, Etage A of Bohemia and Pebidian of Wales (Hicks).

Fossil.—Eozoon Bavaricum, Gumbel.

2. *Upper Huronian.* In Canada—Conglomerates, slates and grits of Eastern Newfoundland; Kewenian group of Lake Superior. European equivalents not certainly known.

Fossils.—Aspidella Terra-novica, Billings; *Arenicolites.*

Distribution.—The Huronian is extensively developed on the north side of Lake Huron and south and west of Lake Superior. It occurs also in Newfoundland and New Brunswick, and probably in various parts of eastern Quebec and the Atlantic States. It contains extensive deposits of iron, copper and silver.

Note.—The precise relations of the Hastings group of Eastern Ontario, and various other groups of altered rocks resembling it in mineral character, with the Huronian, are not yet well understood.

Fig. 26.—Section of Huronian, &c., Lake Superior. (After Chamberlain.) (*a*) Laurentian, (*b*) Huronian, (*c*) Kewenian, (*d*) Potsdam.

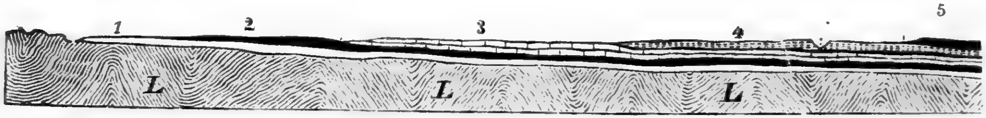


Fig 27.—Superposition of Cambrian and Silurian on Laurentian in Quebec and Ontario. (1) Cambrian. (2) Siluro-cambrian. (3) Silurian (4) Devonian. (5) Carboniferous.

PALÆOZOIC PERIOD.

I. Cambrian System.

1. *Lower Cambrian.* In Canada—Quartzite and slate of the Atlantic coast of Nova Scotia, with *Astropolithon, Scolithus* and *Eophyton.* European equivalents—Longmynd series of England, Harlech grits and Llanberris shales of Wales, Etage B of Bohemia, Eophyton shale of Scandinavia.

Fossils.—Sponges, Worms, Polyzoa, Brachiopoda, Pteropoda, Trilobites, appear first in the Lower Cambrian.

2. *Middle Cambrian.* In Canada—Acadian group of New Brunswick and Newfoundland, Lower Potsdam in part of Lower St. Lawrence. European equivalents—Menevian slates and flags of Wales, Lower alum slates of Sweden, Etage C of Bohemia.

Fossils.—*Paradoxides, Conocoryphe* and other Trilobites characteristic. Also *Lingulella, Orthis, Discina, Eocystites,* &c.

3. *Upper Cambrian.* In Canada—Potsdam sandstone and lower Calciferous of Quebec and Ontario, fossiliferous Cambrian of Miré, Cape Breton. European equivalents—Lingula flags and Tremadoc slates and sandstones of Great Britain; Upper alum slates of Sweden.

Fossils.—*Scolithus, Lingula, Dikelocephalus* and *Protichnites* characterize the typical Potsdam. Various Corals, Crinoids, Lamellibranchs, Heteropods, Gasteropods and Cephalopods occur in the upper member, which shows transition to the next age.

Distribution.—The Lower Cambrian is best developed on the Atlantic coast of Nova Scotia, where it constitutes the gold-bearing series. The Middle Cambrian occurs in eastern Newfoundland and southern New Brunswick. The Potsdam is extensively developed in the western part of the Province of Quebec and in New York, where it often rests directly on the Laurentian.

II. Siluro-cambrian System.

(Lower Silurian of Murchison.)

1. *Quebec Series.* In Canada—Shales, limestones and sandstones of Point Levis, and the south side of the Lower St. Lawrence. In the United States a belt extending southward through Vermont and New Hampshire. European equivalents—Llandeilo

series in part; Arenig (Skiddaw and Borrowdale) of England; Etage D1, Bohemia; Lower Graptolithic slates of Scandinavia.

Fossils.—Graptolites of Genera *Graptolithus, Phyllograptus, Dendrograptus, Diplograptus, Dictyonema,* &c. Trilobites of Genera *Dikelocephalus, Agnostus, Arionellus, Bathyurus,* &c., Land plants? *Protannularia* of Skiddaw series.

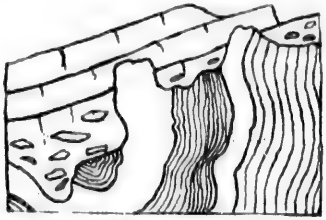


Fig. 28.—Superposition of Siluro-cambrian limestone on quartzite and slate of Hastings series, Hog Lake, Ontario.

2. *Trenton Series.* In Canada—Chazy, Black River and Trenton limestones of Quebec and Ontario. Corresponding rocks of the New York series. European equivalents—Bala Formation of England and Wales; Etage D2 of Bohemia; Regio C, or Oeland limestone of Scandinavia; Graptolite and Calymene slates of France—Second Fauna of Barrande.

Fossils.—Rich invertebrate Fauna of Corals, Crinoids, Brachiopods, Lamellibranchiates, Gasteropods, Cephalopods and Crustaceans. The following are very characteristic in Canada—*Stenopora fibrosa, S. Petropolitana, Glyptocrinus ramulosus, Columnaria alveolata, Tetradium fibratum, Ptilodictya acuta, Strophomena alternata, Leptaena sericea, Orthis lynx, Lingula quadrata, Cyrtodonta Huronensis, Murchisonia bellicincta, Pleurotomaria subconica, Conularia Trentonensis, Asaphus megistos, Trinucleus concentricus.*

In Nova Scotia and New Brunswick the Trenton and Quebec series appear to be represented by the Graptolite slates of Northern New Brunswick, and by the felsites, agglomerates, slates, &c. of the Cobequid Mountains, &c. in Nova Scotia, which have been named the Cobequid series. They resemble in mineral character the Borrowdale series of England.

3. *Hudson River Series.* In Canada—Utica shale of the St. Lawrence Valley, shales, coarse limestones and sandstones overlying the Utica in various parts of Ontario and Quebec, and extending southward into the United States. European equivalents—Caradoc sandstones and shale. Regio D of Scandinavia; Etages D3, D4, Bohemia.

Fossils—Continuation of Invertebrate Fauna of Trenton in part, with some new types, as *Favistella stellata, Halysites gracilis, Pterinea demissa, Asaphus Canadensis, Triarthrus Beckii* and *T. spinosus. Graptolites* abound in some parts of the Utica, especially *G. pristis, G. bicornis* and *G. ramosus.* Earliest certainly known Land plants — *Protostigma, Annularia, Sphenophyllum, Eopteris.*

Distribution.—Formations of this age occur in patches along the northern coast of the Gulf and River St. Lawrence, on the north side of Anticosti and on the south side of the St. Lawrence from Gaspe. From Bay St. Paul upward, they occupy both sides of the St. Lawrence and the Valley of the Lower Ottawa. as far up as the Thousand Islands. Westward of this they form a broad belt extending across Ontario from Lake Ontario to Georgian Bay. They occur in the Islands of Georgian Bay and the North Channel, and at River St. Mary cross over into the United States. They reappear in the Valley of the Red River.

III. Silurian System.

(Upper Silurian of Murchison.)

1. *Medina Series.* In Canada—Sandstones of the West end of Lake Ontario and extending thence into the United States. Lower part of Anticosti series. European equivalents—Llandovery formation of Wales or beds of passage, including the Mayhill sandstone. Etage E1 Bohemia.

Fossils.—The trails known as *Arthrophycus*, and *Lingula Cuneata* are characteristic.

2. *Niagara Series.* In Canada—Clinton and Niagara limestone of Ontario, and their extension southward into the United States. Lower Arisaig and New Canaan slates of Nova Scotia; Upper Silurian limestones and slates of Northern New Brunswick and Gaspe in part. European equivalents—Wenlock limestone and shale of England. Etage E2 of Bohemia.

Fossils.—The Niagara limestone contains a rich marine fauna: *Astylospongia praemorsa, Stromatopora concentrica,* and Corals, &c. of the genera *Favosites, Halysites, Heliolites, Dictyonema*; Crinoids, as *Stephanocrinus* and *Caryocrinus*; Mollusks, as *Strophomena rugosa, Pentamerus, Spirifer Niagarensis.* Trilobites of genera *Dalmania, Lichas, Calymene,* and *Illaenus,* are characteristic. *Glyptodendron* of the Clinton is probably a Lycopodiaceous plant.

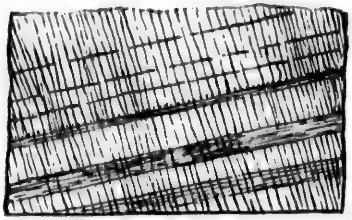


Fig. 30.—Silurian shales affected with slaty sleavage, Matapedia River.

3. *Salina Series.* In Canada—Shales, marls, dolomites and rock salt of Goderich in Ontario. This is a local series confined to the interior basin of North America, and marking a period of elevation and dry climate with deserts and salt lakes. The Guelph or the Galt limestone of Ontario is a transition deposit between this and the Niagara. The fossils are few—*Megalomus Canadensis*, a large lamellibranchiate, is characteristic of the Galt limestone. There are also species of *Murchisonia*, *Cyclonema*, &c.

4. *Helderberg Group.* In Canada—Limestone of St. Helen's Island, Montreal; Oriskany, &c., of Ontario; Cape Gaspe limestone; Upper Arisaig series, Nova Scotia. European equivalents—Ludlow Series of England; Etage F, G, of Bohemia.

Fossils—Pentamerus galeatus, P. pseudo-galeatus, Rhynchonella ventricosa. Species of *Merista, Chonetes, Eatonia* and *Stricklandinia, Tentaculites* and *Eurypterus*, are characteristic. Fossil plants of genus *Psilophyton* occur. Earliest fossil fishes—Placoganoids and Selachians.

Distribution.—The Silurian rocks are well developed in the district extending north-westward from the Niagara river to Lake Huron. They occupy a large area in Quebec and Northern New Brunswick, extending S.W. from Gaspe and the Bay de Chaleur; and isolated areas occur in Nova Scotia and Southern New Brunswick.

IV. Erian System.

(Devonian of English Geologists).

1. *Corniferous Series*—Corniferous limestone and associated sandstones in Ontario, Lower Gaspe sandstones. European equivalents—Plymouth and Linton groups of Devon; Eifel limestones, spirifer sandstone of Germany; old red sandstone of Scotland and West of England.

Fossils—Placoganoid and Ganoid fishes abound. Abundant corals of genera *Favosites, Heliophyllum, Eridophyllum, Cystiphyllum, Zaphrentis,* &c. Plants—*Prototaxites Logani* and *Psilophyton princeps.*

3. *Hamilton Series.*—Hamilton shales of Western Ontario, Middle part of Gaspe sandstones, Corduite shales of St. John New Brunswick. European equivalents—Middle Devonian of England and Scotland; upper part of Eifel formation.

Fossils.—*Spirifer mucronatus* and *Atrypa reticularis* and *aspera* are common. The genus *Goniatites* appears. Fishes of genera *Dinichthys.* Trilobites of genus *Phacops.* Numerous fossil plants of the genera *Calamites, Lepidodendron, Psilophyton, Archaeopteris, Cordaites,* &c. The earliest insects, (*Platephemera,* &c.) appear in the St. John shales. Earliest Decapods, (*Palaeopalemon*).

4. *Chemung Series.* In Canada—Shales &c. of Kettle Point Lake Huron, Upper Gaspe sandstone, Upper sandstone and conglomerate of St. John, New Brunswick. European equivalents—Upper old red sandstone of Scotland, Kiltorcan beds in Ireland, Petherwin group of Devon, Cypridina shale of Germany.

Fossils.—Many Lamellibranchiates of genera *Pteronites, Avicula,* &c. Fishes of genus *Holoptychius, Pterichthys,* &c. Ferns of genus *Archaeopteris, Cyclopteris.* &c.

Distribution. These rocks occupy the peninsula of Ontario between Lakes Erie and Huron. They occur largely in the region south of Lake Erie and elsewhere in the United States. They are extensively developed in Gaspe and the Bay de Chaleur and also in Southern New Brunswick. In the maritime regions however, last mentioned, the great limestones, so rich in corals in Ontario, are wanting.

V. Carboniferous System.

I. *Horton Series.* Lower Carboniferous Shales and Conglomerates, Horton Bluff, &c., in Nova Scotia. Equivalents in United States—Vespertine group of Pennsylvania; Waverly sandstone (in part), Ohio; Kinderhook and Marshall groups of Illinois and Michigan; lower or false coal measures of Virginia. European equivalents—Tweedian group or Calciferous sandstones of Scotland; Carboniferous shale and Coomhala grits of Ireland; Culm formation of Germany, Graywacke of Vosges.

Fossils.—Fishes of genera *Rhadinichthys, Rhizodus, Acrolepis, Ctenacanthus,* &c. Footprints of earliest known Batrachians: *Lepidodendron corrugatum, Cyclopteris Acadica, Cordaites,* &c.

2. *Windsor Series.* In Canada—Lower Carboniferous limestones and gypsiferous series of Nova Scotia and New Brunswick. Equivalents in United States—Burlington, Kekuk and Chester limestones of Illinois. European equivalents—Old Mountain or Carboniferous limestone of England; Calcaire Condrusien of France; Kohlen-kalkstein of Germany; Fusulina limestone of Russia.

Fossils.—Marine Invertebrates of genera *Fusulina, Lithostrotion, Cyathophyllum, Fenestella, Productus, Terebratula, Athyris, Spirifer, Aviculopecten, Macrodon, Conularia, Nautilus, Orthoceras, Phillipsia,* &c.

3. *Millstone grit.* Canadian types—Sandstones and conglomerates between the Carboniferous limestones and the coal formation, in Nova Scotia and New Brunswick. In United States—Seral conglomerate of Pennsylvania, Lower Carboniferous sandstone of Kentucky, Alabama and Virginia, Chester group of Illinois in part. European equivalents—Millstone grit and Yoredale rocks of England; Moor rock of Scotland; Jungste Grauwacke of the Hartz, Saxony and Silesia.

Fossils.—Plants similar to those of the Coal formation.

4. *Coal Formation.* In Canada—Productive coal measures of Nova Scotia and New Brunswick. In United States—coal formation of Pennsylvania, Ohio, Illinois and Michigan, represented in the west by marine limestones, &c. In Europe—the coal formations of Scotland, England, France, Germany, &c.

Fossils.—Land plants of genera *Araucaroxylon, Sigillaria, Lepidodendron* and *Calamites*, and *Ferns* and allied plants. Fishes of genera *Palaeoniscus, Rhizodus, Diplodus, Gyracanthus, &c.* Batrachians of genera *Baphetes, Dendrerpeton, Hylonomus, Anthracosaurus,* &c. Insects, Millepedes, Arachnidans and Decapod Crustaceans.

Distribution.—In Canada the Carboniferous occupies considerable areas in Nova Scotia and New Brunswick, and includes the extensive and valuable coal fields of Cumberland, Pictou and Cape Breton. Small areas of the Permo-carboniferous occur in the south of Prince Edward Island; and the Lower Carboniferous, locally termed the Bonaventure formation, extends into the east of Quebec. A limited area, including beds of coal, occurs in western Newfoundland. In the west, rocks of Carboniferous age occur in the Rocky Mountains and in British Columbia, but without beds of coal.

VI. Permian System.

1. *Lower Permian.* Canadian type—Permo carboniferous red sandstones of Prince Edward Island and Eastern Nova Scotia. In United States—Permian sandstones of Virginia and limestones of Kansas and Nebraska. Upper Carboniferous beds of Illinois, holding remains of reptiles. European equivalents, Lower Permian sandstones of England, Rotheligendes of Germany, Lower Permian Sandstones and Limestones of Russia.

Fossils.—For the most part generically similar to those of the Carboniferous. The earliest true reptiles appear.

2. *Upper Permian.* Not represented in Canada, but marine limestones of this age occur in Kansas and westward. In England it is represented by the important formations of the Marl slate and Magnesian limestone; in Germany by the copper slate and zechstein; and in Russia by the copper sandstones and gypsiferous limestone.

Fossils.—Reptiles of genus *Proterosaurus.* Fishes of genus *Palaeoniscus.* Mollusks of genera *Pseudomonotis, Myalina, Productus, Fenestella,* &c.

MESOZOIC PERIOD.

I. Triassic System.

1. *Bunter Sandstone.* In Canada—Lower new red sandstone of the Bay of Fundy and Prince Edward Island, associated with trappean rocks. In United States—Lower red sandstones of Connecticut and New Jersey. In the West, red and magnesian limestones overlying Carboniferous of Rocky Mountains. In Europe—Bunter sandstein of Germany, Lower Triassic red sandstones of England.

Fossils.—Conifers and Cycads. Footprints of Dinosaurs.

2. *Muschelkalk.* A marine limestone found in Germany and Eastern France, but not represented in England or Eastern America. In British Columbia and the Western United States the Triassic sandstones and slates with volcanic rocks, and the *Monotis* shales, may be partly of this age, and it may also be represented in the East by part of the Triassic coal formation of Virginia and South Carolina.

Fossils (in Europe)—*Encrinus moniliformis, Avicula socialis, Ceratites nodosus, Pemphyx Sueri,* &c. Fishes—*Hybodus,* &c. Reptiles—*Nothosaurus,* &c.

3. *Keuper Sandstone.* In Canada—Upper Triassic sandstones of Prince Edward Island and Bay of Fundy, and probably portions of the Trias of British Columbia. In United States—Upper red sandstone of North Carolina, &c. To the Upper Triassic are also usually referred the Mesozoic Coal beds of Virginia and North Carolina with their associated Sandstones and shales. In Europe—Saliferous series of England; Keuper formation of Germany.

Fossils.—Plants, *Equisetum, Pterophyllum,* &c. Reptiles, &c., *Bathygnathus borealis,* footprints of Dinosaurs, *Labyrinthodon giganteum.* The earliest Marsupial mammals (*Microlestes, Dromatherium*).

Distribution of the Triassic in Canada.—This formation occupies the greater part of Prince Edward Island and the basin of the Bay of Fundy, where its trappean beds form the "North Mountain" of Cornwallis and Annapolis. Rocks of this age also appear in the Rocky Mountains, in British Columbia and the Queen Charlotte Islands; but in these Western regions their mineral character is very different from that which they present in the East.

II. Jurassic System.

1. *Lias.* Not represented in Canada, unless some of the shales and sandstones overlying the Trias of Peace River are of this age. Not represented in the Eastern United States, unless some of the rocks referred to the Upper Trias are its equivalents. In England, the gray limestones and shales of Lyme Regis, &c. rich in Saurian remains. Similar beds with marls, &c., are extensively distributed in France, Switzerland, Italy, and Suabia.

Fossils (in Europe)—This group is rich in marine shells. *Ammonitidae* abound. *Pteroceras, Paludina* and other modern genera of gastropods appear. *Leptaena, Spirifera* and other old genera of Brachiopods become extinct. *Ostrea* and other recent forms of Lamellibranchs appear. *Enaliosaurs* are abundant and crocodiles of the genus *Teleosaurus* appear. Cycads and conifers are the most abundant fossil trees.

2. *Jurassic proper,* or *Oolitic Series.* Not represented in Canada, except perhaps by porphyrite and other volcanic rocks

in British Columbia, and shales and sandstones of Rock Island, Peace River. Limestone and marl of Black Hills and elsewhere in Western United States. In Europe—Lower, Middle and Upper Oolite of England, with the intervening Oxford and Kimmeridge clays. Also very largely represented in France and the Jura Mountains and elsewhere in Europe. The Lower or Bath Oolite of England is remarkable for oolitic structure. The Stonesfield slate, a flaggy series connected with the Lower Oolite, is noted for vegetable remains and remains of mammals and insects. The Lithographic slate of Solenhofen has many interesting fossils and is of the age of the Middle Oolite. It has afforded the earliest known bird, *Archæopteryx macrurus.* The Upper or Portland Oolite is overlaid by a fresh-water formation, the Purbeck, which has afforded many mammalian remains and land plants, and also fresh-water snails allied to *Planorbis.*

Fossils.—Remarkably rich in Cephalopods, especially *Ammonitidæ* and *Belemnitidæ.* Also in Reptiles, as *Pterodactyls, Dinosaurs, Enaliosaurs, Crocodileans, Turtles,* &c.

III. Cretaceous System.

1. *Lower Cretaceous* or *Neocomian.* In Canada—Tatlayoco lake sandstone and conglomerate, with *Aucella Piochii,* and underlying porphyries; and perhaps the coal series of Queen Charlotte Island and Quatseno Sound, in British Columbia; Shasta group in California; possibly Dakota group of Western Territories and its extension north of the 49th parallel; Lower Cretaceous clays of New Jersey, &c. In Europe—Hastings sand, Weald clay, and lower greensand of England, and their equivalents on the continent.

Fossils.—Dinosaurian Reptiles, *Ignanodon* and *Hylæosaurus,* &c. Appearance of Teleost fishes, and of Angiospermous Exogens of modern types. *Crioceras, Ancyloceros,* and *Ammonites* abundant; *Diceras.*

2. *Middle Cretaceous* or *Cenomanian.* In Canada—Niobrara limestones and clays of Western Territories and Western States of the Union. This is an extensive marine formation, rich in Foraminifera with *Ostrea congesta* and species of *Inoceramus* and *Baculites.* In Europe—the Gault clay, Upper Greensand and Chalk marl of England and the continent of Europe.

Fossils.—Species of *Hamites, Scaphites, Turrilites, Lima, Ostrea,* &c., are characteristic in Europe.

3. *Upper Cretaceous* or *Senonian*. In Canada—Ft. Pierre and Fox Hill clays and sandstones of the Western Territories, and continuation to the South. Greensand of New Jersey with associated clay and limestone. White or Upper chalk of England and other parts of Europe, and white limestones of North Africa and Western Asia, Mæstricht limestone of Denmark.

Fossils.—Vast numbers of Oceanic Foraminifera, especially *Globigerina;* Coccoliths; Sponges of genus *Ventriculites*, &c.; Echinoderms of genera *Ananchites, Galerites, Marsupites, Cidaris*, &c.; Lamellibranchs of genera *Inoceramus, Spondylus, Ostrea*, &c., Cephalopods of genera *Belemnitella, Baculites, Nautilus*, &c., Reptiles of genera *Mosasaurus, Clidastes, Hadrosaurus;* toothed birds of genus *Icthyornis, Hesperornis*, &c. The flora of this period contains a large preponderance of modern types.

Distribution.—The Cretaceous rocks occupy a broad belt extending on the 49th parallel from near the Red River to the Souris River and thence to the north-west. They also occur on the Saskatchewan and head waters of the Missouri farther to the west. Considerable areas occur in British Columbia, the most important being that which includes the Nanaimo and Comox coal-field on Vancouver Island.

The Cretaceous Period is remarkable, in both the eastern and western continents, for a prevalence of estuarine and fresh-water conditions in its earlier portion, and for a great subsidence, producing oceanic conditions over wide areas now land, in its middle and later portion. It is also marked by the decadence of the reign of reptiles, and by the introduction of the modern flora in the continents of the Northern Hemisphere.

KAINOZOIC PERIOD.

I. Eocene Age.

1. *Lower Eocene* (*Orthrocene*). In Canada this formation is probably represented by the Lignite Tertiary formation of the Western Territories, the Lignitic or Laramie group of the American geologists, whic[illegible]ts of estuarine and fresh-water sandstones and shales, [illegible] reptilian remains, lignite and fossil plants of modern types. It is however regarded by many geologists as more nearly related to the Upper Cretaceous than to the Eocene proper. Fig. 28, and the section on p. 33, repre-

sents parts of this group, which is very extensively distributed in the region between the Red River and the Rocky Mountains and thence southward. In England the typical formations are the London clay, plastic clay and Thanet sands, holding marine and estuarine shells and fossil fruits and wood. The Argile Plastique and Sable Bracheux represent it in the Paris basin. In these beds, in Europe, the oldest known placental mammals occur, *Hyracotherium*, *Lophiodon*, *Coryphodon*. Marine invertebrates of living species also appear, though as yet in small numbers, about three per cent. of the whole.

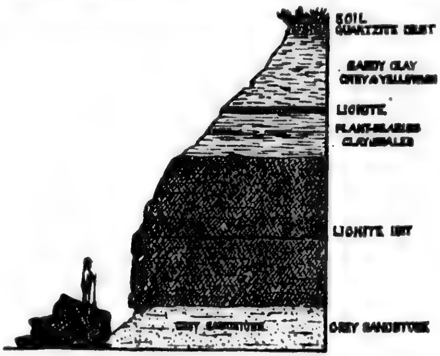


Fig. 28.—Lignite Bed. Porcupine Creek, N. W. T.—(G. M. Dawson.)

2. *Middle Eocene*, or *Eocene proper* (*Nummulitic*). Not as yet recognized in Canada. In the United States this series is represented by the clays, marls, sands and coarse limestones of the Claiborne series of Alabama, holding marine shells and bones of *Zeuglodon*. In the west the great lake basins of the Wahstach have afforded remains of many land animals (*Coryphodon*, *Tillodontia*, *Eohippus*, &c.) In Europe the most characteristic and wide-spread formations are the Calcaire Grossier of the Paris Basin and its associated marine sands, and the Nummulitic limestones extending from Western Europe to India, and marking a great subsidence. In England the Bracklesham and Alum Bay series are of this age.

3. *Upper Eocene* (*Proicene.*) Not recognized in Canada. In the United States represented by the marine clays and Orbitoidal limestone of Alabama, Mississippi, &c. (Vicksburg group),

and in the West by fresh-water clays and sands (Bridger group, &c.), containing *Dinoceras*, *Unitatherium*, *Orohippus*, &c. In Europe the best known representative is the Gypseous series and Silicious Limestone of the Paris Basin, and the upper beds of the Isle of Wight series in England. These formations abound in mammalian remains (*Anchitherium*, *Palæotherium*, *Anoplotherium*, *Xyphodon*, earliest *Lemuridæ*).

II. Miocene Age.

1. *Lower Miocene.* Not recognized in Canada, unless represented by the volcanic rocks, sandstones and shales with lignite and fossil plants of Nicola, Similkameen, &c., in the interior of British Columbia. In America the subdivisions of the Miocene have not been distinctly separated, but the age is represented by the New Jersey, Virginia, &c. middle Tertiary sands, clays, marls and infusorial deposits; and in the West by the Middle Tertiary lake basins of White River, &c., east of the Rocky Mountains. In the latter, three subdivisions are characterized by Marsh as respectively those of the *Brontotherium*, *Oreodon* and *Miohippus*. The Miocene beds hold a larger percentage of recent shells than the Eocene (17 to 30 per cent.), and abound in mammalian remains (*Brontotherium*, *Titanotherium*, *Oreodon*, *Machairodus*, &c.) In Englaud—Hempstead beds of Isle of Wight and lignites of Bovey Tracey. In France—Calcaire de Beauce and Sables de Fontainebleau, with equivalent deposits in Germany, Italy, &c. The basalts of Antrim and the Hebrides are of this age. Living genera of mammals, as *Rhinoceros*, *Tapirus*, *Mustela*, *Sciurus*, &c., appear in the Lower Miocene.

2. *Middle Miocene.* Falunien of France, Middle or marine Molasse sandstone of Switzerland. Genera *Mastodon*, *Dinotherium*, *Sus*, *Antilope*, *Cervus*, *Felis*, *Dryopithecus*, &c.

3. *Upper Miocene.* In Europe, Molasse of Oeningen in Switzerland, Léberon and Epplesheim beds of France, Pikermi formation in Greece. Additional modern genera of mammals, as *Camelopardalis*, *Gazella*, *Hyæna* and *Hystrix* appear.

A very equable and warm climate seems to have prevailed in the Eocene and Miocene, so that plants of genera now living in temperate climates were abundant in Greenland and Spitzbergen.

III. Pliocene Age.

1. *Older Pliocene.* Not recognized in Canada. In United States, Sumter clays and sands of North and South Carolina. In the West, Loup River group of Niobrara, containing remains of Camel, Rhinoceros, Horse, &c. In England, Coralline Crag and Red Crag.

2. *Newer Pliocene.* Not recognized in Canada, nor distinguished in the United States from the older Pliocene. In England, Norwich Crag and Chillesford Clay.

In the Pliocene, the percentage of recent shells rises to 50 or more. Mammalia of modern genera are abundant, and a few modern species appear. In the later Pliocene the land both of Europe and America seems to have been more elevated and extensive than at present (First Continental period of Lyell). The climate of the Northern Hemisphere was cooler than in the Miocene.

IV. Pleistocene Age.

This was characterized throughout the Northern Hemisphere by a great refrigeration of climate, followed or accompanied by a submergence of the land to a depth exceeding in some places 5000 feet. The formations of the period are well represented in Canada, and may be taken as types, more especially as from their great extent and uniformity they are free from some of the complications which have caused controversy elsewhere.

1. *Boulder Clay.* At the beginning of the Pleistocene the land was higher than at present. At this time the mountain tops were extensively occupied with glaciers, which have left their traces in all the elevated ground. Very deep valleys and ravines were also excavated by the rivers. Beds of peat were accumulated, and gravels and sands in low grounds, in lake basins and on coasts. Gradual subsidence then set in, under which the valleys were invaded by cold Arctic currents laden with field ice and bergs, while the high levels still sent down glaciers. Under these circumstances moraines were formed on the land, and sheets of stony clay with boulders in the sea, forming what has been termed the boulder clay or "Till," and extensively polishing and striating the surfaces of rocks.

In the deposits of this period Arctic shells are found, though not abundantly, and also trunks of boreal coniferous trees. At

Fig. 29.—Boulder (11 feet long) on glaciated surface. Lake of the Woods.

the beginning of the age, however, there were in Europe and America forests of temperate and boreal type, and a great number of mammals, some extinct, some still surviving, and presenting a remarkable mixture of boreal and temperate forms. Remains of these occur in peaty beds under the boulder clay. By the progress of the glacial cold and subsidence, these animals were destroyed or compelled to migrate to the southward.

2. *Leda Clay, Erie Clay.* This marks the greatest subsidence and the gradual emergence of the land. It is a fine stratified clay, sometimes however with large boulders, and thus passing into boulder clay. It has on the Atlantic slopes of America and Europe numerous marine fossils, especially in its upper part; and these are mostly of species still inhabiting the North Atlantic and North Pacific. Farther inland it contains some remains of plants and land animals. The Leda clay is equivalent to the Clyde beds and Uddevalla beds of Europe. There is reason to believe that the great subsidence which closed in this period reached to 2300 feet in the mountains of Wales, and to 4000 feet in those of North America. It was probably greatest toward the north. At the beginning of the deposit of Leda clay, the shells indicate cold water covered with floating ice. Toward its close (Upper Leda clay or Uddevalla beds) the marine climate must have been little different from that now occurring in the same latitudes on the western side of the Atlantic.

3. *Saxicava Sand and Second Boulder Drift.* This marks the re-elevation which ended in a second continental period, raising the continents to a greater elevation than at present.

The climate was still somewhat cold, and large boulders carried by floating ice abound in the Saxicava sand, but are most abundant at its base.

The Pleistocene deposits are sometimes called *Quaternary*; but there is no good ground for separating them from the Kainozoic or Tertiary. The term "Champlain" deposits has been applied to them in the United States; but the Lake Champlain beds are those of a limited valley among mountains and are not typical or characteristic.

Some writers include in the Pleistocene the next or post-glacial age; but it is more nearly connected in its physical conditions and its animal life with the modern period.

Dawkins catalogues, for this period in Britain, 1 mammal surviving from the Pliocene and still living, 7 surviving from Pliocene and extinct, 67 new species, of which 14, including elephants and other large and important species, are now extinct.

V. Modern Age.

This extends from the close of the glacial or Pleistocene age to the present time, and is divisible into two well-marked periods.

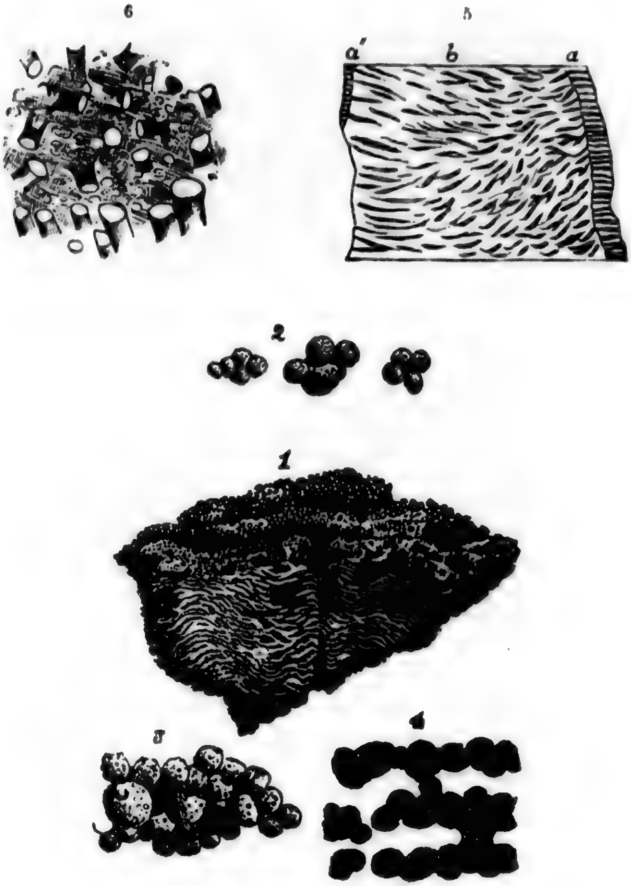
1. *The Post-Glacial.* (Second Continental Period of Lyell.) In this the land of the Northern Hemisphere was more extensive than at present. The climate was temperate but somewhat extreme. All the modern mammals, including man, seem to have been in existence, but several others now extinct, as the Mammoth, the Tichorhine Rhinoceros and the Cave Bear, lived in the Northern Hemisphere, and many still extant differed very remarkably in their geographical distribution from that of the present time. To this period belong the human remains of the early cave deposits and river gravels of Europe, or of the "Mammoth age" (Palæocosmic or Palæolithic age). This period was terminated by a submergence or series of submergences which with their accompanying physical changes proved fatal to many species of animals and to the oldest races of men, and left the continents at a lower level than at present, from which they have risen in the recent period. In Britain Dawkins catalogues 22 living and 6 extinct species survivors of the Pleistocene in this period, and 18 new forms still living. The 6 extinct species include 2 species of elephant, 2 of rhinoceros, the

cave bear, and the great Irish elk. It is evident therefore that man comes in with a fauna in the main modern, but including a few large and important species which have perished since his advent, and many others which have much changed their range.

2. *The Recent* or *Historic Period.* This dates from the settlement of our continents at the present levels after the Post-glacial subsidence. It is the period of Neocosmic or Neolithic men of races still extant. I have called this the Historic Period, because in some regions history and tradition extend back to its beginning. The historical deluge is in all likelihood identical with the movements of the land above referred to, by which this age was inaugurated; though in certain localities, as in America, the beginning of the historic period is very recent. In this age man coexists wholly with existing species of mammals, and the races of men are the same which still survive. The whole forms geologically one period, and the distinctions made by antiquarians between stone, bronze and iron ages, and under the former between palæolithic and neolithic, are merely of local significance, and connected with no physical or vital changes of geological importance.

Laurentian Fossil.

Eozoon Canadense. Portion of a large specimen. Nature-printed.



Laurentian Fossils.

Eozoon Canadense. (1) Small specimen disengaged by weathering. (2) Acervuline cells of upper part—magnified. (3) Tuberculated surface of lamina—mag. (4) Laminæ of Serpentine in section, representing casts of the sarcode—mag. (5) Section magnified showing canal system at (*b*) and tubuli at (*a*). (6) Canals highly magnified.

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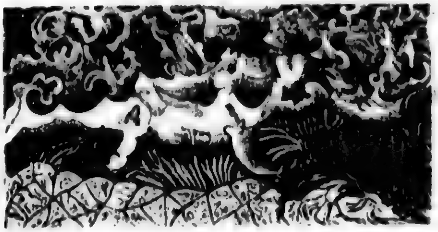

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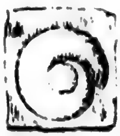

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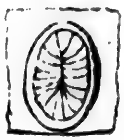

HURONIAN FOSSILS.

Fig 1. Cast of worm burrows, Madoc (Hastings group)—magnified. *a.* Containing rock. *b.* Space filled with calcite. *c.* Sand agglutinated and stained black. *d.* Sand uncoloured. Figs. 2, 3. Another specimen, nat. size, and mag. Fig. 4. *Eozoon Bavaricum* × 25 (after Gumbel). *a, b,* calcite. *c.* tubuli. *d, e.* Casts of contorted chambers. Fig. 5. *Arenicolites.* Fig. 6. *Aspidella terranovica*—Billings. The two last from Upper Huronian of Newfoundland.

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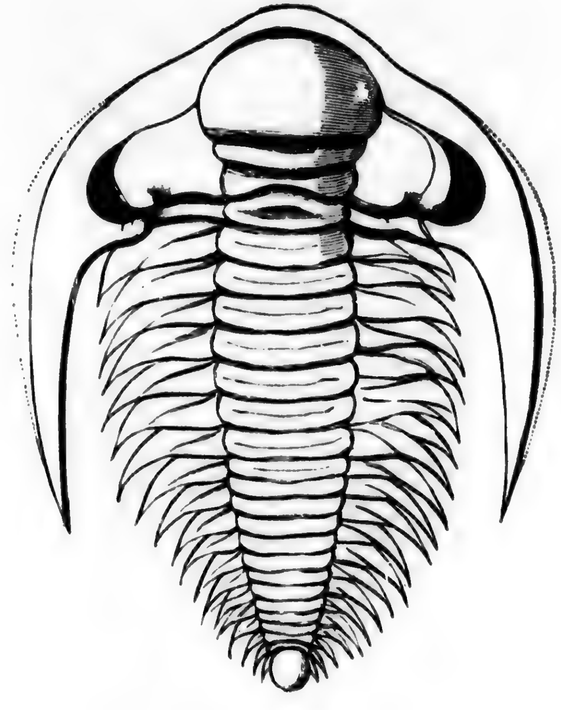

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MIDDLE CAMBRIAN FOSSILS.

Fig. 1. *Paradoxides Micmac.* 2. *Conocephalites* (*Conocoryphe*) *Matthewi.* 3. *Orthis Billingsi.* 5. *Discina Acadica.* 4. *Lingulella Matthewi.*—Acadian group, St. John, N. B.

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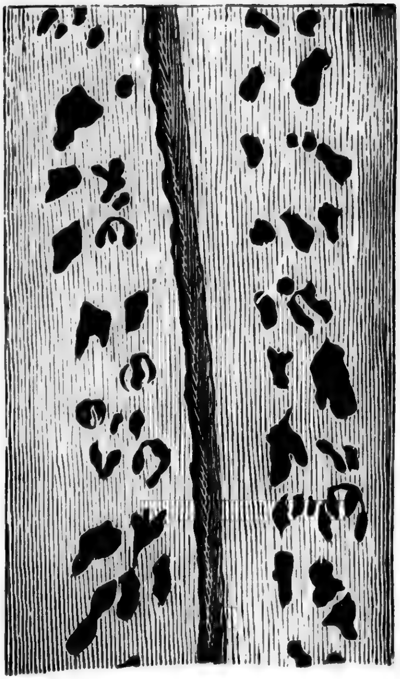

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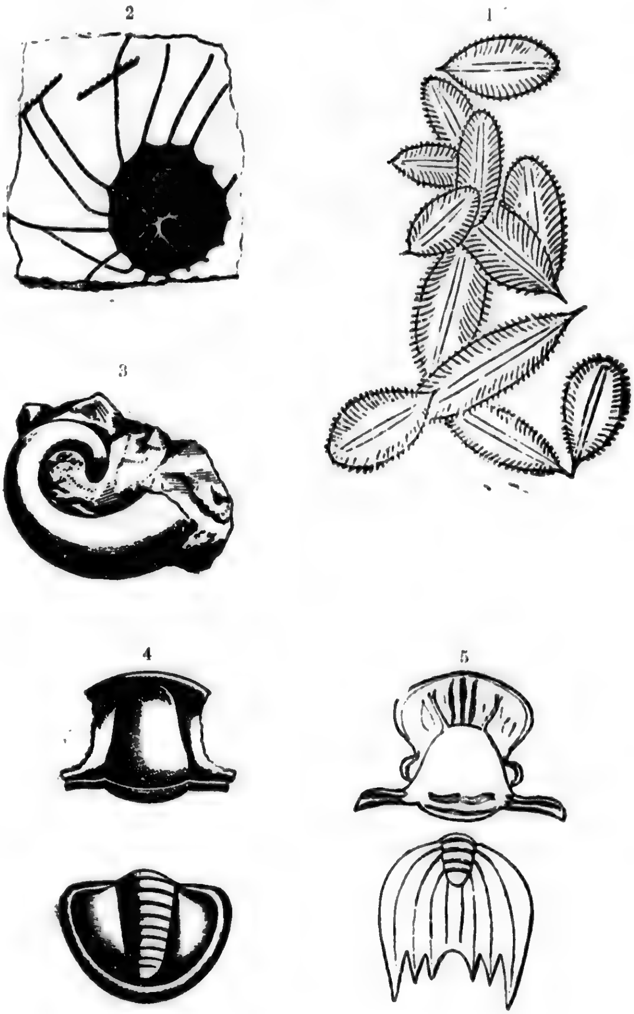
UPPER CAMBRIAN FOSSILS.

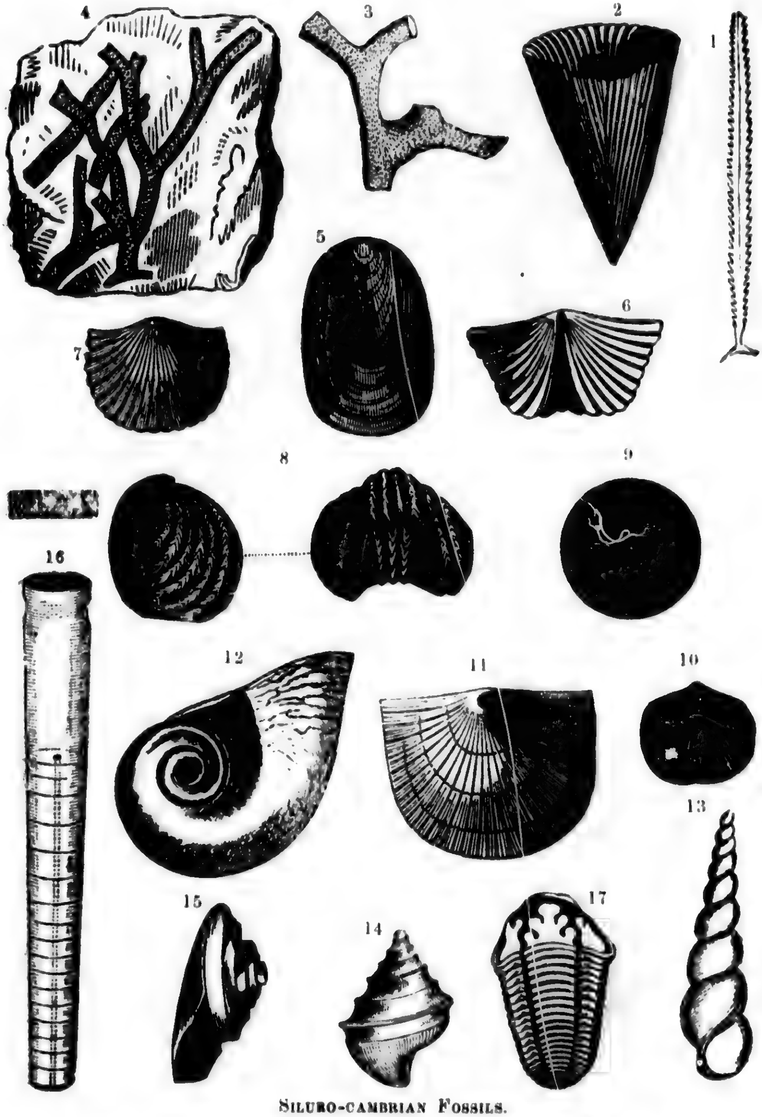
Fig. 1. *Protichnites septem-notatus*, Potsdam.

2. *Ligulella antiqua*. (*c*) Short variety. (*d*) Long variety.



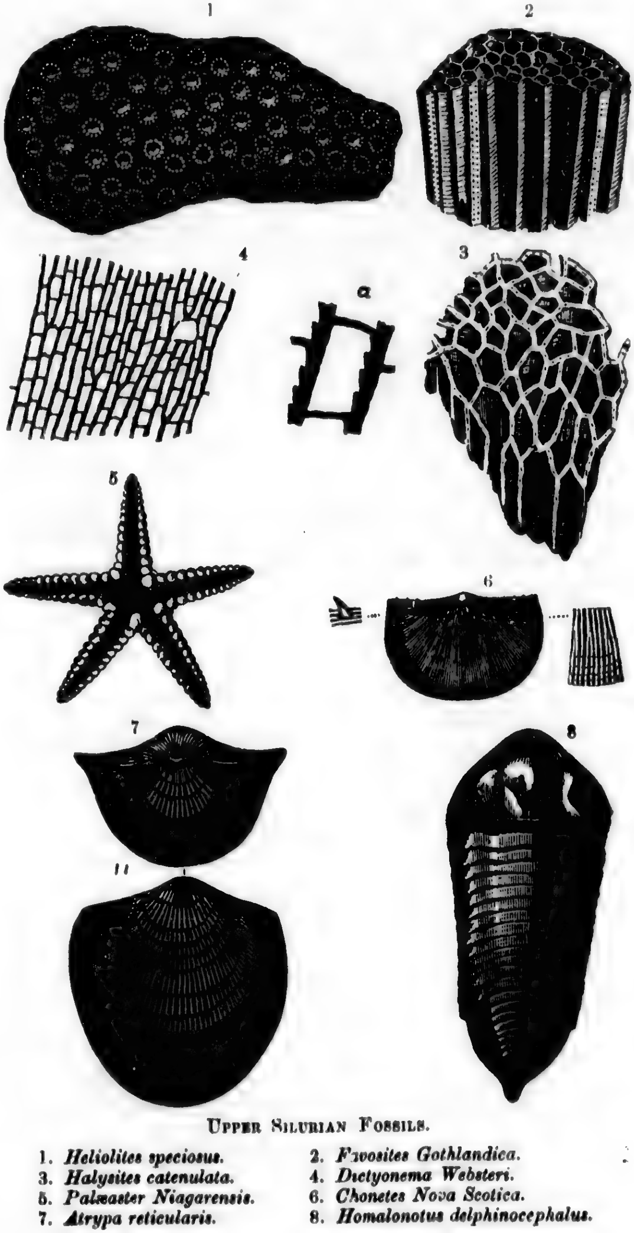
SILURO-CAMBRIAN FOSSILS. (Quebec Group.)

Fig. 1. *Phyllograptus typus.* 2. *Graptolithus Logani.*
3. *Ecculiomphalus intortus.* 4. *Bathyurus Saffordi.*
5. *Dikelocephalus magnificus.*



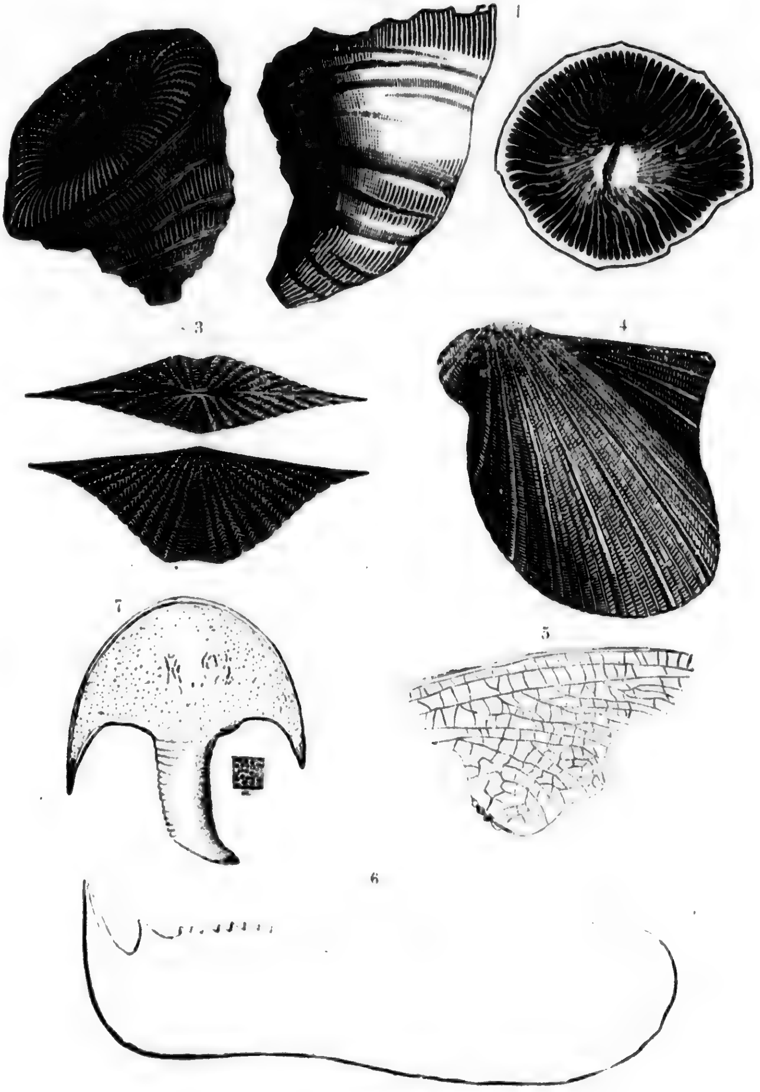
SILURO-CAMBRIAN FOSSILS.

Fig. 1. *Graptolithus bicornis.* 2. *Petraia profunda.* 3. *Stenopora fibrosa.* 4. *Ptilodictya acuta.* 5. *Lingula quadrata.* 6. *Orthis lynx.* 7. *Orthis pectinella.* 8. *Rhynchonella increbrescens.* 9. *Discina circe.* 10. *Orthis testudinaria.* 11. *Strophomena alternata.* 12. *Bellerophon Sulcatinus.* 13. *Murchisonia gracilis.* 14. *M. bicincta.* 15. *Pleurotomaria umbilicatula.* 16. *Orthoceras* sp. 17. *Calymene senaria.*



UPPER SILURIAN FOSSILS.

1. *Heliolites speciosus.*
2. *Favosites Gothlandica.*
3. *Halysites catenulata.*
4. *Dictyonema Websteri.*
5. *Palæaster Niagarensis.*
6. *Chonetes Nova Scotica.*
7. *Atrypa reticularis.*
8. *Homalonotus delphinocephalus.*

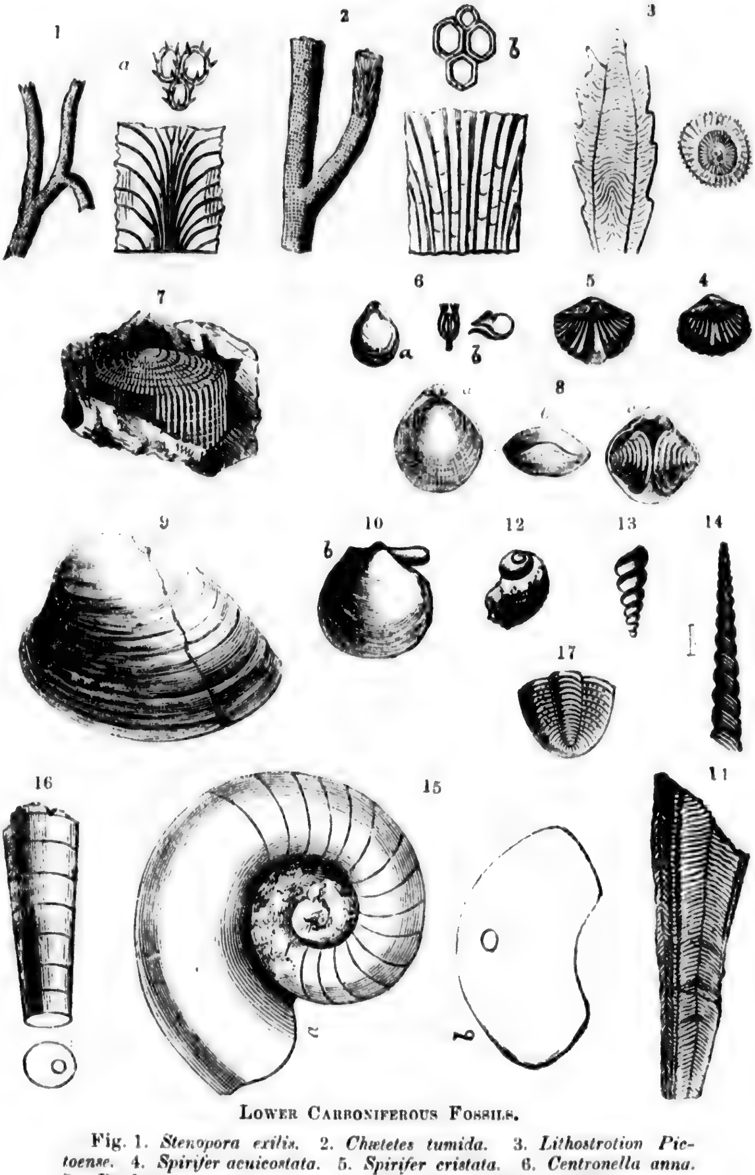


ERIAN OR DEVONIAN FOSSILS.

1. *Zaphrentis prolifica.* 2. *Heliophyllum Halli.*
3. *Spirifer mucronatu*. 4. *Pterinea flabella.*
5. *Platephemera antiqua.* 6. Jaw *of Dinichthys* (reduced).
7. *Cephalaspis Dawsoni* (reduced). (*a*) Sculpture.

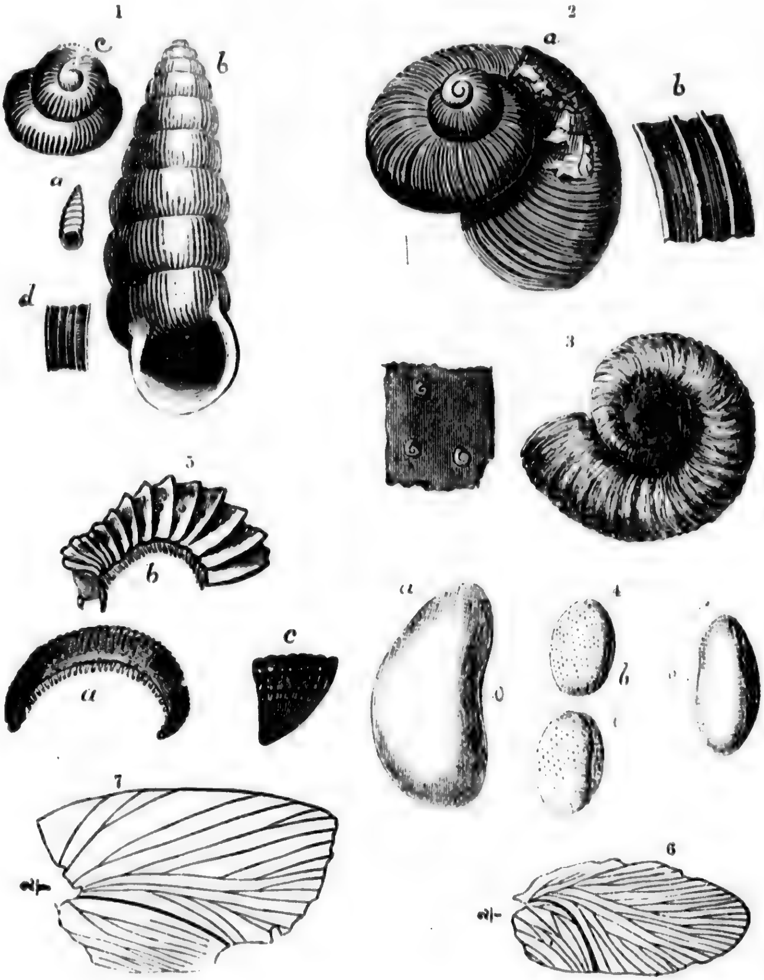
ERIAN OR DEVONIAN PLANTS.

1. *Archaeopteris Jacksoni*, (*a*, *b*) portions showing venation.
2. *Sphenophyllum antiquum*, (*a*) magnified, (*b*) natural size.
3. *Asterophyllites parvula*, (*a*) nat. size, (*b*, *c*) portions magnified.



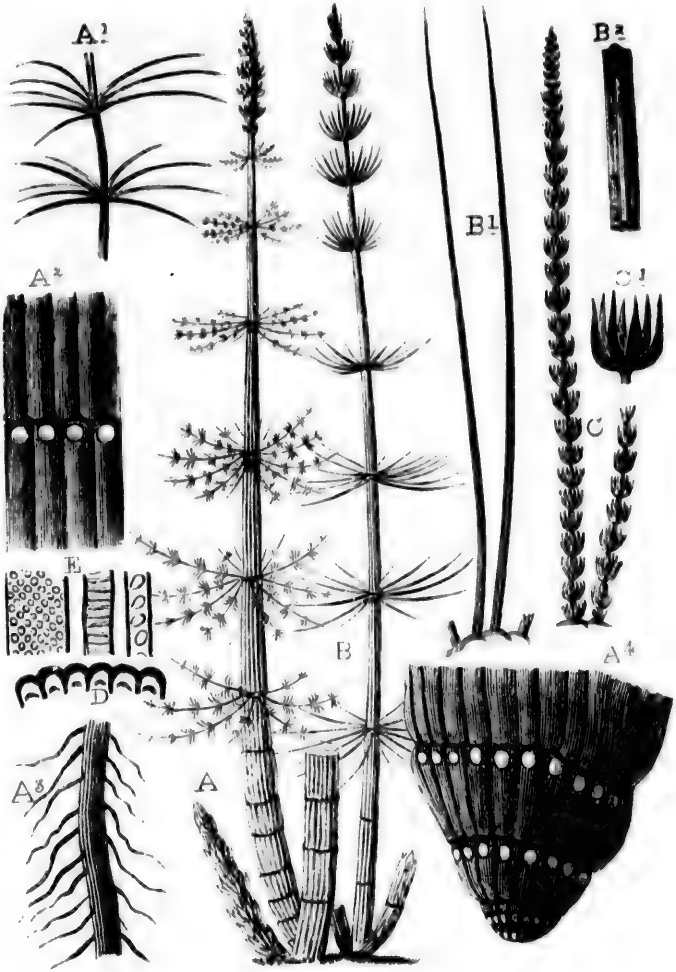
Lower Carboniferous Fossils.

Fig. 1. *Stenopora exilis.* 2. *Chætetes tumida.* 3. *Lithostrotion Pictoense.* 4. *Spirifer acuicostata.* 5. *Spirifer cristata.* 6. *Centronella anna.* 7. *Productus semireticulatus.* 8. *Athyris subtilita.* 9. *Cardiomorpha vindobonensis.* 10. *Aviculopecten simplex.* 11. *Conularia quadrisulcata.* 12. *Naticopsis dispassa.* 13. *Murchisonia gypsea.* 14. *Loxonema acutula.* 15. *Nautilus avonensis.* 16. *Orthoceras vindobonense.* 17. *Phillipsia Howi.*



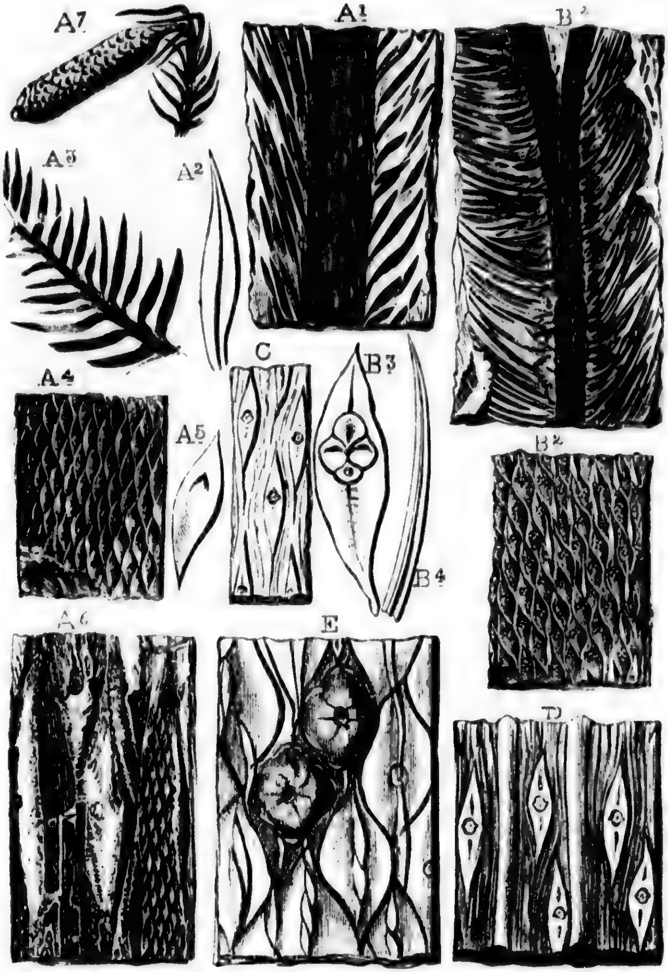
COAL-FORMATION FOSSILS.

Fig. 1. *Pupa vetusta.* 2. *Conulus priscus.* 3. *Spirorbis carbonarius.* 4. *Entomostracans,* (*a*) *Bairdia,* (*b*) *Cytherella,* (*c*) *Cythere.* 5. *Millipedes,* (*a*) *Xylobius sigillariæ,* (*b*) *Archiulus Xylobioides,* (*c*) *Xylobius farctus,* 6. *Blattina Bretonensis.* 7. *Blattina Heeri.*



CARBONIFEROUS CALAMITES.

A *Calamites Suckovii*, restored.
A1 Foliage.
A2 Ribs and Scars.
A3 Roots.
A4 Base of stem.
B *Calamites Cistii*, restored.
B1 Leaves.
B2 Leaf enlarged.
C Leaves of *C. nodosus*.
C1 Whorl, enlarged.
D Structure of stem.
E Vessels, magnified.



CARBONIFEROUS LEPIDODENDRA.

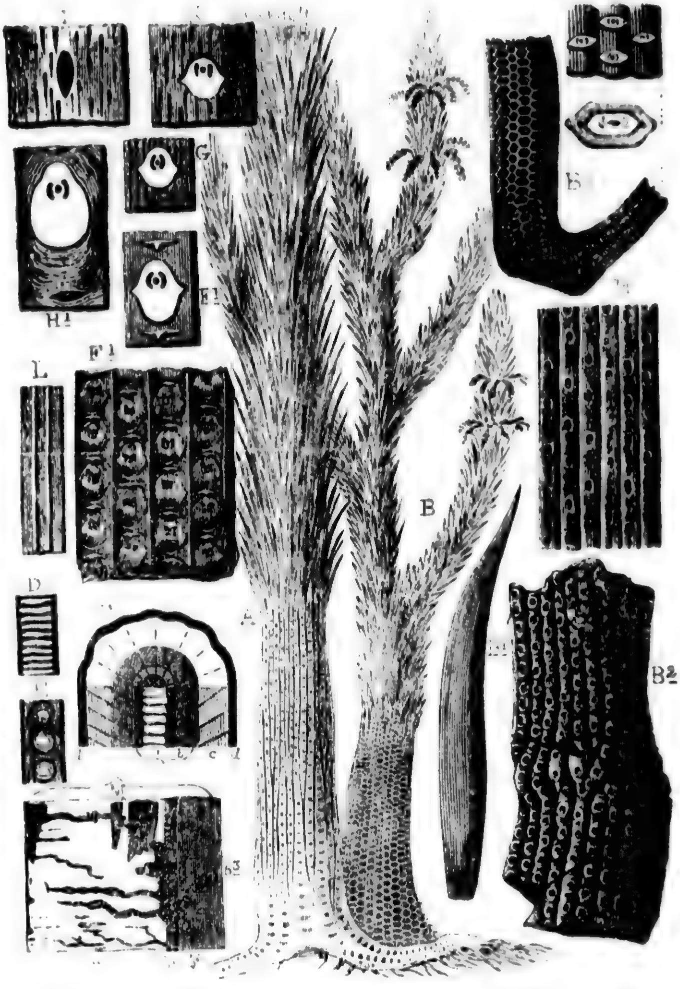
A Branch and leaves of *L. Pictoense*, $\frac{2}{3}$ nat. size. A^2 Leaf. A^3 Twig and leaves, $\frac{2}{3}$. A^4 Portion of bark, $\frac{2}{3}$. A^5 Leaf-scar. A^6 Bark of old stem furrowed by growth, $\frac{2}{3}$. A^7 Cone, $\frac{2}{3}$.

B *L. personatum*, leafy branch, $\frac{2}{3}$. B^2 Portion of bark, $\frac{2}{3}$. B^3 Areole enlarged. B^4 Leaf.

C *L. plicatum*, bark of old stem.

D *L. rimosum*, old stem with furrows, $\frac{2}{3}$.

E *L. undulatum*, showing furrows and scars of cones, $\frac{2}{3}$.



CARBONIFEROUS SIGILLARIÆ.

A *Sigillaria Brownii*, restored. B *S. elegans*, restored. B1 Leaf of *S. elegans*
B2 Portion of decorticated stem, showing one of the transverse bands of fruit-scars.
B3 Portion of stem and branches, reduced—and scars, nat. size.
C Cross section of *S. Brownii* (?), reduced, and portion at (M), nat. size. (*a*) Sternbergia pith, (b^1) Scalariform vessels. (b^2) Discigerous cells, (*c*) Inner bark. (*d*) Outer bark.
D E Tissues, mag. F *Sigillaria Bretonensis*, ⅔. G *S. striata*. H *S. eminens*, reduced. I *S. catenoides*. K *S. planicosta*. L Leaf.

IMAGE EVALUATION TEST TARGET (MT-3)

6"

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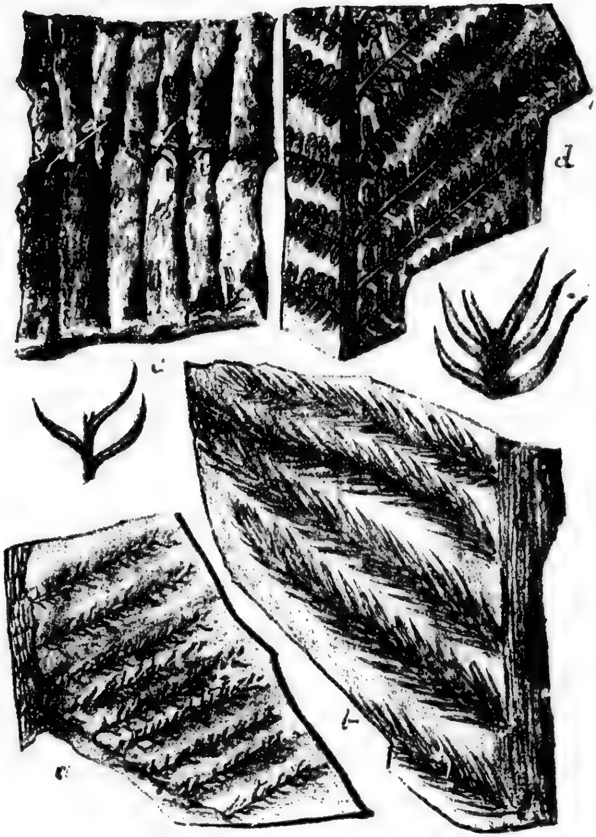
CARBONIFEROUS FERNS.

A *Odontopteris subcuneata* (after Bunbury).
B *Neuropteris cordata* do.
C *Alethopteris lonchitica.*
D *Dictyopteris obliqua* (after Bunbury.)
E *Phyllopteris antiqua*, mag. (E^1) nat. size.
F *Neuropteris cyclopteroides.*



PLANTS OF THE PERMO-CARBONIFEROUS.

(Prince Edward Island.)

(*a*) *Walchia gracilis.* (*b*) *W. robusta.*
(*c*) *Calamites gigas.* (*d*) *Pecopteris arborescens.*

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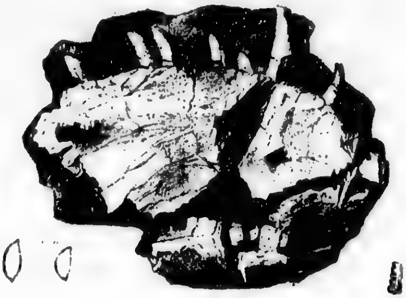

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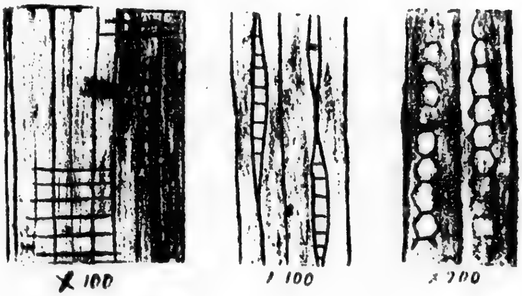
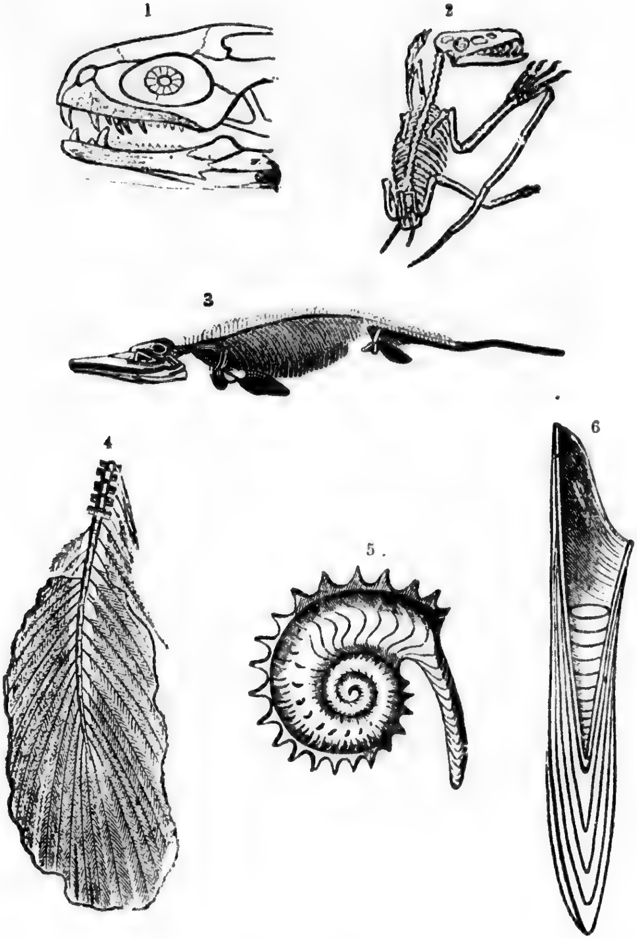


TRIASSIC FOSSILS.

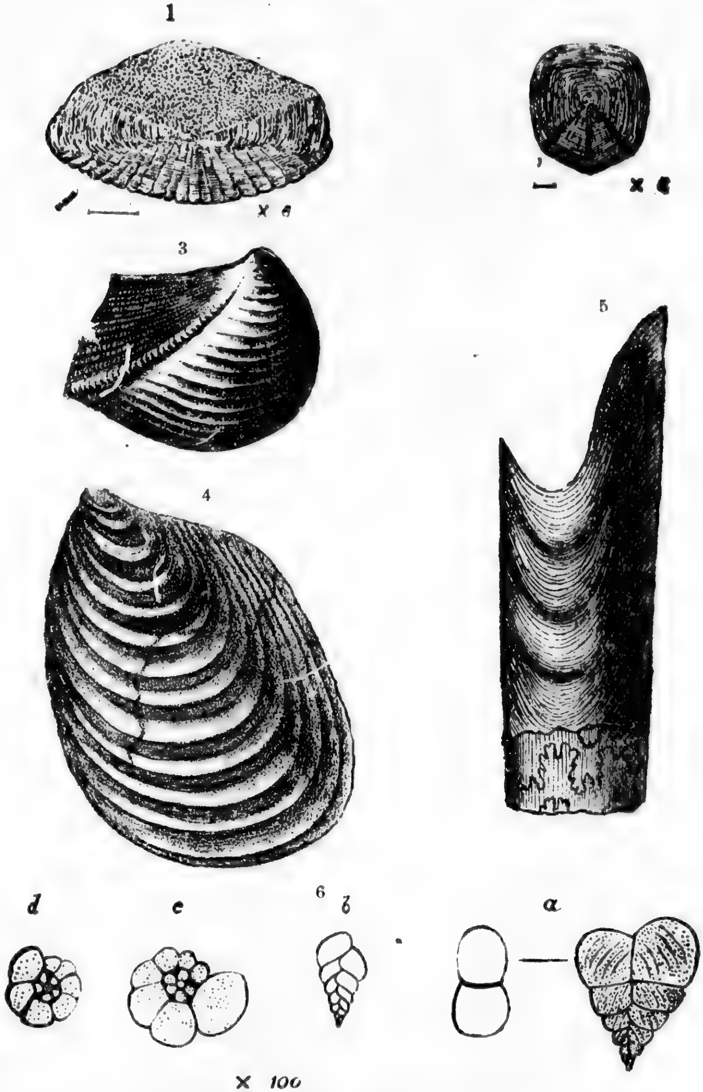
(Prince Edward Island.)

Fig. 1. *Bathygnathus borealis* (Lower jaw), reduced.
2. *Araucaroxylon Edvardianum* (Structures magnified.)



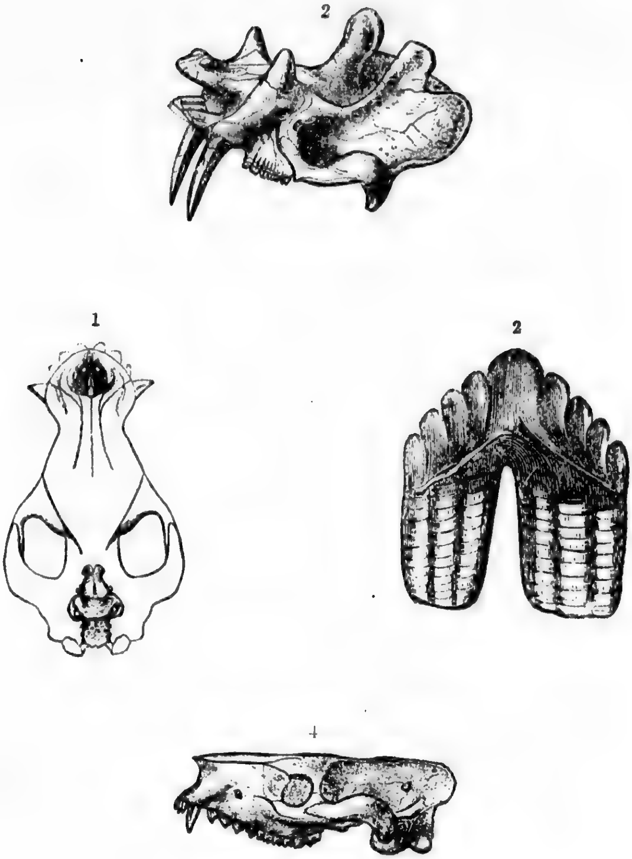
JURASSIC FOSSILS.

1. Head of *Megalosaurus*.
2. *Pterodactylus crassirostris*
3. *Ichthyosaurus communis*.
4. Tail of *Archæopteryx*.
5. *Ammonites Jason*.
6. *Belemnites* (section).



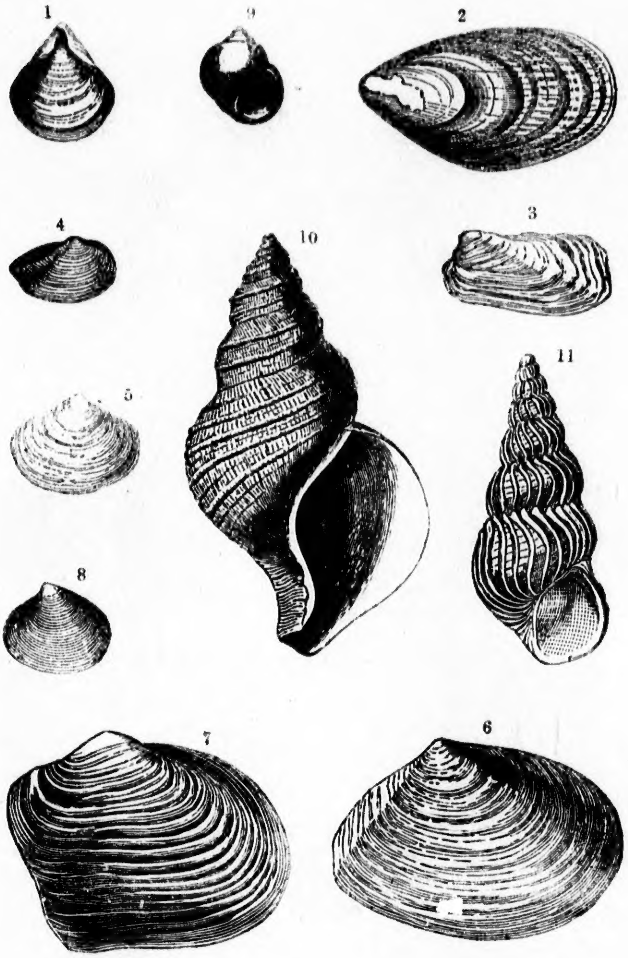
CRETACEOUS FOSSILS. (Western America.)

1. & 2. Scales of Teleost Fishes, N. W. Territory.
3. *Trigonia Americana.* 4. *Inoceramus Vancouverensis.*
5. *Baculites ovatus.* 6. Foraminifera, Boyne R., Manitoba,
(a) *Textularia globulosa,* (b) *T. pygmaea,* (c) *Planorbulina ariminensis.*



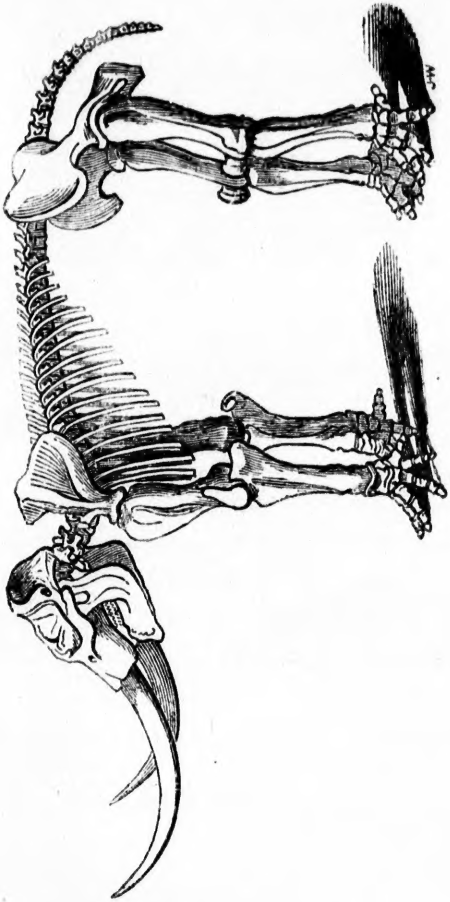
KAINOZOIC MAMMALS.

1. *Coryphodon hamatus* (Eocene).
2. *Zeuglodon cetioides*—tooth (Eocene).
3. *Dinoceras mirabilis* (Eocene).
4. *Oreodon major* (Miocene). (All reduced.)

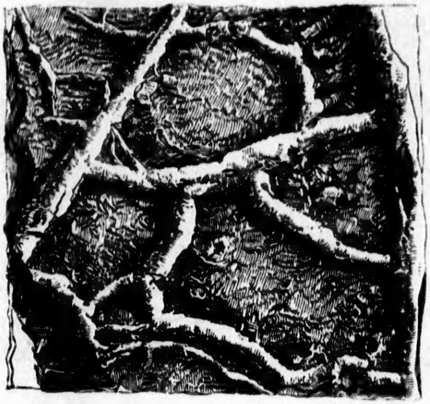


PLEISTOCENE FOSSILS.

1. *Rhynchonella psittacea.*
2. *Mytilus edulis.*
3. *Saxicava rugosa.*
4. *Leda (Portlandia) arctica.*
5. *Tellina (Macoma) Grœnlandica.*
6. *Tellina (Macoma) calcarea.*
7. *Mya truncata.*
8. *Astarte (Nicania) Laurentiana.*
9. *Natica clausa.*
10. *Fusus tornatus (Neptunea despecta)*
11. *Scalaria Grœnlandica.*



Mastodon Americanus (Pleistocene and modern).



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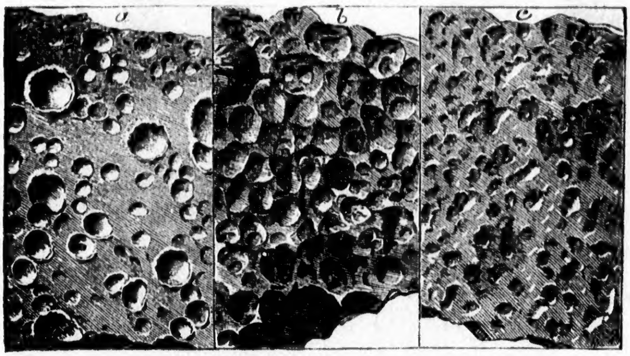

3

Fig. 1. Shrinkage cracks Carboniferous (reduced).
2. Rain-marks, (*a*) modern, (*b c*) Carboniferous.
3. Rill-marks, Carboniferous (reduced).